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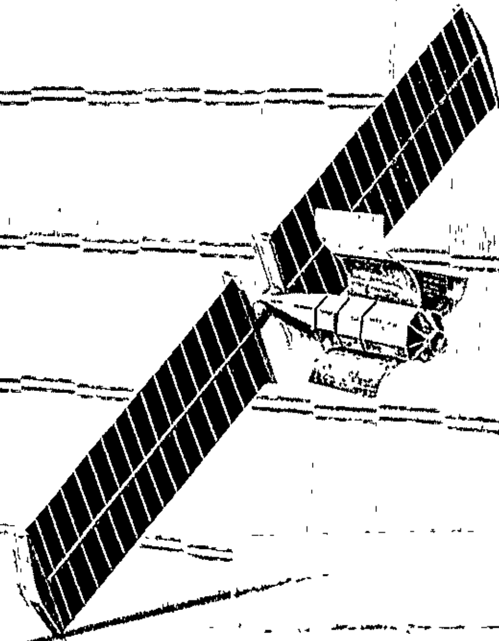

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George C. Marshall
Space Flight Center

25 kW POWER MODULE EVOLUTION STUDY

PART 1 — FINAL REPORT
PAYLOAD REQUIREMENTS AND GROWTH SCENARIOS

LOCKHEED MISSILES & SPACE COMPANY, INC.

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FINAL REPORT

25 kW POWER MODULE EVOLUTION STUDY

PART I
PAYLOAD REQUIREMENTS AND GROWTH SCENARIOS

1 AUGUST 1978

FOR

National Aeronautics and Space Administration
George C. Marshall Space Flight Center

Contract No. NAS8-32928
DPD 555
DR No. MA-04

LOCKHEED MISSILES & SPACE COMPANY, INC.
Sunnyvale, California

FOREWORD

This document presents the final report for Part I, Payload Requirements and Growth Scenarios, for the 25 kW Power Module Evolution Study. The report fulfills the Part I deliverable data requirement of NASA/Marshall Space Flight Center Contract No. NAS8-32928, as defined in DPD 555 for Data Requirement No. MA-04.

Separate reports will be produced to document the results of Part II and Part III of the study. In addition, technical description documents will be prepared for the 25 kW Power Module baseline system and for the selected evolutionary supporting elements. These five reports will comprise the final technical report for the study. An executive summary document will also be produced at the conclusion of the study.

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BACKGROUND AND SYNOPSIS

This Part I study is the first of a three-part study. In outline form the total study scope is as follows:

Part I – Payload Requirements and Growth Scenarios (LMSC/TRW)
A 3-month analytical effort to develop payload application summaries and time-phased requirements which will drive the concepts for the Power Module evolution and the Supporting System definitions.

Part II – Definitions of Evolutionary Systems (LMSC/Bendix/IBM)
A 7-month effort to establish baseline program support elements and candidate evolutionary growth options for final candidate Power Module and Support System elements (Element data, costs, modifications, development sequence, precursor missions).

Part III – Conceptual Designs of Selected Evolutions (LMSC/Bendix)
A 5-month conceptual design effort to establish design approaches for two or more preferred evolutionary Power Module growth systems.

This report summarizes the results of Part I of the 25 kW Power Module Evolution Study conducted for NASA/MSFC by LMSC. It had as its objective the definition of selected future space payload requirements and a general definition of their potential impact upon the baseline and growth versions of the 25 kW Power Module (PM). Parts II and III are devoted to definition of the PM and associated Support System elements and possible modifications thereto (Shuttle Orbiter, Spacelab modules and pallets, External Tank, etc.) which will be required to support the payload requirements. Results of Parts II and III will be reported separately.

The Part I study covered the total time span from 1983 (the proposed IOC date for the initial PM) through the 1990's. Because of the need for establishing the early payload driver requirements for the PM, heavier emphasis was placed upon the earlier payloads which are planned for flight implementation in the 1983 to 1986 period.

The following paragraphs outline the Part I study highlights and are intended to provide a general and overall insight into the following report, which is presented in accordance with NASA/MSFC format requirements as basic charts (right hand pages) and facing text pages which elaborate upon the chart data.

Part I Study Content

The Part I effort comprised four basic areas which are described on pages 1A-4 and 1A-5:

- Analysis of User Requirements
- Time-Phased Scenarios of Payload Implementation
- Summary of Payload Requirements Impacting the PM
- Summary of Payload Requirements Impacting the PM

Although initially it was planned to provide a separate set of requirements for separate payload disciplines and subsequently for mixed-discipline payload groupings, it became apparent early in the study that the proposed future payloads were in a strong dynamic change status (explained later) and could not be summarized in firm multi-discipline terms. NASA/MSFC approval was therefore obtained to concentrate upon three separate payload disciplines for the Part I study; these are discussed in some detail in this report:

(1) Materials Processing in Space
(2) Public Services (Communications)
(3) Solar/Terrestrial

Analysis of User Requirements and Dynamic Status

A large variety of payload data were obtained from NASA and industry; listings of the primary elements and contacts are shown on page 1A-9. A bibliography listing of published documents is provided in the Appendix 1 hereto. In addition, numerous direct contacts were made with Principal Investigator – type personnel to obtain additional data on proposed payloads and estimates of support requirements therefore.

In most cases the payload concepts offered in the published data were based upon (1) the relatively short duration of Orbiter operation with limited-power Spacelab installations; (2) the use of a manned space platform, or (3) the continued use of autonomous free-flying payload/spacecraft combinations.

Most of the existing payload data reviewed at the beginning of the study as a data base were principally devoted to the 1980 – 1982 hardware concepts (Spacelab early missions). It became very evident as the study progressed, a dynamic state of flux was occurring in the User areas: They were responding affirmatively to the prospect of availability of a Power Module and were expanding their plans to include its advantages. A heavy conversion of payload concepts were beginning to appear, evidenced by:

- Extended-duration Orbiter sortie flights, supported by a PM, with increased payload power requirements per flight
- Free-flyer payload missions, supported by a PM

These newer concepts made possible by the PM availability resulted in concept redirection of man-tended payloads to longer-duration automated payloads which could be free-flown attached to the PM.

As a result of this additional PM space support capability, the current payload planning is in transition. However, in the three payload emphasis disciplines selected, operational scenarios and power requirements were carefully updated after LMSC review with NASA/MSFC of the latest PM-oriented payload plans which had been coordinated between MSFC and NASA/HQ. Although additional refinements may be made by the User personnel, the requirements shown in this report for the emphasis disciplines are considered reasonable for initial implementation of the PM and later growth versions thereof. As other User disciplines areas complete their replanning, using the PM, the total system usage of the PM can be further assessed. NASA/HQ is working with the various Agencies through the PM Payload Working Groups to this end.

Payload Concepts, Requirements, and Scenarios on Emphasis Disciplines

After early attempts to collect and document specific characteristics of post – 1983 payloads from seven disciplines (see page 1A-7), it became clear that many payload concepts and characteristics were either: (1) established for the pre-Power Module period and could not readily be converted to PM usage without considerable concept design or (2) hardware concepts and key operating characteristics were not available. Because of limited resources and time constraint of the Part I study, it was therefore agreed with NASA/MSFC to focus upon the three aforelisted emphasis disciplines, wherein MSFC was already doing considerable planning for conversion of the payload systems to PM usage. The latest planning and data were coordinated closely with the responsible payload offices at MSFC and with the study COR, Don Saxton.

Sections 1B, 1C, and 1D of this report separately summarize the planned program and requirements for respectively the Materials Processing in Space (MPS), Public Services (PS), and Solar/Terrestrial payload disciplines. The time-phased operational scenarios are presented, payload basic configurations and hardware content are discussed, and requirements pertinent to the Power Module are listed. The payload individual concepts have not been completed (this was beyond the scope of the study), but the size and mass of payload elements have been shown to aid in the concepting of the PM support systems. Also, the general interfaces with the PM or other support equipment have been described. In some cases, a PM concept is outlined, but it is not intended to infer specific configuration nor size. Part II of the study will determine the required PM arrangement to support the payloads.

Payload Power Estimates

The power level estimates for the payloads include the power for the mission-dependent and mission-peculiar support equipment but do not include power for support of personnel in the Spacelab sortie mode nor the support of personnel habitats or workshops (labs) on the manned platforms. The man-support requirements are added later in the PM power summaries in Section 1G.

Other Payload Disciplines

Section 1E of the report summarizes data on four disciplines beyond the three emphasis disciplines: Astrophysics/Astronomy, Earth Observation, Solar Power Satellite, and Life Sciences. Only one of these is a prime single-discipline driver for the PM, the Solar Power Satellite (SPS). The other three can possibly contribute separate payloads to multi-discipline platforms; they were therefore not given significant attention in determining PM driver requirements.

The SPS, however, will possibly be a strong driver for eventual PM growth configurations. Because of the many and highly varied versions of an SPS development plan (two of several proposed but widely divergent scenarios are shown on pages 1E-17 and 1E-18) and the very dynamic status of the SPS funding in DOE and NASA, it was agreed with NASA/MSFC that the SPS would not be included in the payload requirement summaries for the PM at this time.

Multi-Discipline Payload Combinations and Large Structural Platforms

Section 1F illustrates the general concept of multi-discipline platforms. NASA/MSFC is pursuing concept development of at least two types:

- Geostationary Platform (primarily communication payloads)
- Low earth orbit platform

The potential selection of payload combinations to be placed upon an early LEO platform (outlined on page 1F-5) will be limited by the compatibility of the payloads; for example, relative pointing stability, viewing direction, etc.

There are a large variety of proposed large-structure concepts, many of which utilize large crews of personnel operating in EVA or in pressurized manned Teleoperators. It appears that in order to limit the stay-time of the Orbiter in orbit on a particular flight and thereby decrease transportation costs, a manned habitat with relatively small crew complement may provide a cost-effective alternative for large space structure assembly operationsin LEO. These operations will be required for almost all of the larger structures required for GEO platforms, large antennas, or SPS elements.

It therefore may be appropriate to combine large space construction functions with a multi-discipline platform concept and provide a single platform (one per primary orbit inclination in LEO) to provide several functions simultaneously; for example:

- Construction Platform
- Spacecraft Servicing
- Support for Platform-Mounted Payloads:
  a. Operational Payloads
  b. Science Payloads
  c. Development/Test Articles
- Large OTV Assembly and Fueling*
- Personnel and Material Depot for GEO*

*28.5 deg orbit only

Payload Requirement Summaries

Section 1G shows summaries of requirements for the selected payload disciplines. Because of the high potential of usage of a multi-discipline platform or grouping of payloads, power summaries are also shown for this category.

The payload requirements indicate that dedicated Power Modules may be appropriate. However, an alternative of time-sharing a PM, with two or more payload disciplines being supported by a single free-flying PM is also attractive and may be more cost effective and also acceptable to the Users to lower their average tariff for use of the BM.

Follow-on Activity on Payloads

Because of the rapidly-changing payload plans for the 1983 to 1990 period as a result of the Power Module influence, it is necessary to continue an intensive effort to further definitize the future payloads as a firm base for the PM actual hardware design. Recommendations for this activity, upon which NASA has already started PM User Working Group efforts, are briefly outlined in Section 1H.

INTRODUCTION
PART I

OBJECTIVE – PART I

- Part I of the 25 kW Power Module Evolution Study is the first of three parts. Parts II and III are devoted to conceptual definition of the power module that will be required to support the payload requirements defined in Part I.

- Growth versions of the PM, or subsystem derivations thereof, will be largely dependent upon the probable growth of payload requirements.

- Although the NASA payload planning for future missions is dynamic, selected payload disciplines, and their requirements are firmly planned to the degree necessary for determining the PM initial and growth configurations.

- Other space support system elements, such as on the Orbiter, external tank, Spacelab modules and pallets, and others will also be affected by the payload requirements.

- Although the total time span covered for the study is from 1983 through the 1990's, primary emphasis was placed upon the early payload requirements, which tend to drive the PM design.

OBJECTIVE – PART I

- DEVELOP PAYLOAD APPLICATION SUMMARIES AND TIME-PHASED PAYLOAD REQUIREMENTS, BASED UPON NASA FUTURE PLANNING. THESE REQUIREMENTS WILL TEND TO DRIVE THE CONCEPTUAL DEFINITION AND EVOLUTION OF THE 25 kW POWER MODULE AND SUPPORTING SPACE SYSTEMS

- TIME SPAN TO COVER PERIOD 1983 INTO THE 1990s

TASKS AND ACCOMPLISHMENTS – PART I

- The Part I study effort comprised a 3-month analysis of future NASA payload requirements and consolidation into summaries that influence the PM.

- These requirements will be iterated once later in the overall study, as the PM concepts are developed, and may include some updating in key areas which could be influenced by additional payload user data currently being generated by the NASA centers in coordination with NASA/HQ.

- Payload application concepts have been developed only to the extent that:
  - Key driver requirements for the PM can be derived
  - Typical payload interfaces with PM and other support system elements can be shown

- The scope of the study did not include the concept design of specific payloads.

- NASA current program planning for selected payload disciplines was the principal determinant in the choice of typical payload scenarios and payload groupings.

TASKS AND ACCOMPLISHMENTS – PART I

USER DATA REVIEW

- COLLECTED AND ANALYZED USER PAYLOAD REQUIREMENTS FROM NASA AND INDUSTRY

PAYLOAD CONCEPTS/REQUIREMENTS

- DEVELOPED PAYLOAD APPLICATION CONCEPTS ON FUTURE NASA SPACE PAYLOADS AND DERIVED PRINCIPAL REQUIREMENTS

PAYLOAD – GROUP SCENARIOS

- ESTABLISHED GENERAL SCENARIOS FOR KEY (NASA-SELECTED) PAYLOAD GROUPS, BASED UPON NASA PAYLOAD PROGRAM PLANNING

PAYLOAD REQUIREMENTS IMPACTING POWER MODULE

- SUMMARIZED PAYLOAD REQUIREMENTS IN TERMS OF DRIVERS FOR THE POWER MODULE SYSTEM/SUBSYSTEMS

PAYLOAD DISCIPLINES AND REQUIREMENTS ANALYZED

- Data from eight basic payload disciplines were generally collected (with the aid of NASA) and surveyed.

- In early meetings with the PM study COR, it was agreed that the specific review of all disciplines was beyond the resources available in the Part I study; it was agreed to concentrate analysis upon three major areas that seemed to show greatest promise for derivation of early and firm PM drivers:

  - Materials Processing
  - Public Services (Communications and Navigation)
  - Solar/Terrestrial

- Separate sections of this report are devoted to the three emphasis disciplines. The other disciplines are discussed briefly under "Other Payload Disciplines". Multidiscipline payloads are also separately, discussed in conjunction with large space platforms.

- The payload requirements analyzed included those listed on the chart. Each of these has an impact upon the PM design and usage with specific payloads or groups of payloads.

PAYLOAD DISCIPLINES AND REQUIREMENTS ANALYZED

DISCIPLINES

EMPHASIS DISCIPLINES:

- MATERIALS PROCESSING (MPS)
- PUBLIC SERVICES (PS)
- SOLAR/TERRESTRIAL (ST)

- SOLAR POWER SATELLITE (SPS)
- EARTH OBSERVATION (EO)
- ASTRO PHYSICS/ASTRONOMY
- LIFE SCIENCES
- MULTI-DISCIPLINE PAYLOADS/PLATFORMS

REQUIREMENTS ANALYZED

- POWER
- HEAT REJECTION
- MISSION/DURATION
- LOW G
- STABILIZATION AND CONTROL
- CONTAMINATION
- DATA PROCESSING
- ORBIT
- CONFIGURATION/SIZE/MASS
- IOC DATE

PAYLOAD DATA REVIEWED AND PRIMARY CONTACTS

- A large variety of data obtained from NASA, industry, and the Lockheed data bank were reviewed. In many instances, the data on a single payload discipline were quite varied and payload implementation concepts were quite different.

- Also, much of data dealt with payload concepts that preceded the concept of the power module; for example, either long-duration independent free-flyer single payloads or groups of payloads to be carried on shorter Orbiter flight, such as the Spacelab series.

- Meetings with the NASA/MSFC cognizant payload specialists were held to bring much of these data into focus and select or convert payloads which could utilize the PM capabilities.

- The latest NASA/HQ report from the User Needs Working Group (30 May 1978) was reviewed; although no payload hardware concepts were offered, the summary results appear generally correlatable with those in this Part I report.

- TRW provided significant amounts of Materials Processing payload data. The Lockheed Palo Alto Research Lab (LPARL) (with assist from TRW) supplied specific data from which the Solar/Terrestrial payload combinations were derived.

PAYLOAD DATA REVIEWED AND PRIMARY CONTACTS

PAYLOAD DATA

- NASA/HQ 5-YEAR PLAN (1978 – 1983)
- NASA/HQ MISSION MODELS (LATEST – OCT 1977)
- HQ/MSFC REPORTS
- NASA PAYLOAD WORKING GROUP PAPERS
- MSFC PAYLOAD PROGRAM PLANS (PRELIMINARY)
- INDUSTRY REPORTS – NASA STUDY CONTRACTS
- TRW DATA – MATERIALS PROCESSING AND SOLAR TERRESTRIAL
- LPARL DATA – SPACE EXPERIMENTS, STO, ETC.

NASA CONTACTS – MSFC PAYLOAD SPECIALISTS

- MATERIALS PROCESSING – JOHN WILLIAMS, KEN TAYLOR, WALT WOOD
- SOLAR/TERRESTRIAL – RICK CHAPPELL, BILL ROBERTS
- ENERGY SYSTEMS (SPS) – CHUCK GUTTMAN, KEN FIKES
- PUBLIC SERVICES – DON SAXTON, TED CAREY
- ASTROPHYSICS/ASTRONOMY – JIM BALLANCE, MAX NEIN
- MULTI-DISCIPLINE PLATFORM – JIM BALLANCE, CLAY HAMILTON
- LARGE SPACE STRUCTURES – JIM HARRISON

APPROACH AND GROUNDRULES

- Because of the wide variety of payload development concepts offered in the numerous NASA and Industry data, it was agreed that the general mission scenarios proposed by MSFC would be used as baseline for the Part I study. In most cases these development plans have been coordinated by MSFC with NASA/HQ and represent the latest status of overall program planning.

- The payload data developed were directed toward deriving the basic PM-driver requirements and not toward the conceptual design of payloads. However, general data pertinent to PM interfaces have been developed to the extent necessary to evaluate PM and support system concept design.

- Several payload discipline requirements have been firmed up by NASA only for the period of 1981 to 1986. It has been necessary to estimate requirement trends beyond that point.

- Emphasis has been upon identifying principal PM design drivers that will allow greater effectiveness of payloads with PM support. This became increasingly clear when longer-duration free-flyer payloads supported by the PM were considered.

APPROACH AND GROUND RULES — PART I

PAYLOAD ANALYSIS

- USE LATEST PLANS/DATA FROM MSFC PAYLOAD PROGRAM OFFICES
- USE PAYLOADS IDENTIFIED IN LATEST DOCUMENTS AS COORDINATED WITH NASA/HQ
- DIRECTED TOWARD CONSOLIDATED PAYLOAD REQUIREMENTS; NOT TO CONCEPT DESIGN OF PAYLOADS
- NOT TO INCLUDE COSTING, COST-BENEFIT ANALYSIS, NOR PRIORITY RATINGS OF PAYLOADS

STUDY EMPHASIS

- EARLY PAYLOAD MISSIONS 1983 – 1986; EXTRAPOLATE TRENDS BEYOND 1986
- AUTOMATED-EQUIPMENT PAYLOADS FOR EARLY FREE-FLYER APPLICATION
- CONSIDER SPACELAB MODULES/PALLETS, SKYLAB, ET, ETC., FOR PAYLOAD SUPPORT
- EXTEND USER PLANS BEYOND SHUTTLE/SORTIE POWER/DURATION CONSTRAINTS
- IDENTIFY AND EXAMINE PAYLOADS WHICH DRIVE POWER MODULE REQUIREMENTS:
  - POWER
  - EXTENDED DURATION ON ORBIT
  - HEAT REJECTION
  - ATTITUDE CONTROL

MATERIAL PROCESSING IN SPACE (MPS) PAYLOADS

- DATA REVIEW
- PROGRAM OVERVIEW AND TYPICAL SCENARIO
- PROGRAM ELEMENTS AND POWER REQUIREMENTS
- PAYLOAD HARDWARE ELEMENTS
- TYPICAL MISSION CONFIGURATIONS
- POWER MODULE REQUIREMENTS
- CONCLUSIONS

MPS PAYLOADS-DATA REVIEW

- Data reviewed falls generally in two categories
  - near-term plans, through 1982, including considerable detail
  - generalized concepts beyond 1983

- Concurrent with this study, NASA generated as series of requirement projections for MPS payloads, extending through 1986. These projections formed the principal basis for Power Module requirements analysis.

- Concepts for MPS payloads accommodation beyond 1982 have been in rapid flux during the study. They have moved toward emphasis of unmanned free-flyers supported by the Power Module. The purpose for an unmanned approach is not to eliminate man – his presence in space would mean simpler equipment for all experiments and is required for a few. Rather, the purpose is to dilute transportation costs by providing a maximum number of experiments per launch. Major payload impacts are increased automation, increased sample magazine capacities and interchangability.

- Power Module justification is clear. It is needed for the increased duration and power levels for MPS and may well determine initial PM power requirements.

MPS PAYLOADS-DATA REVIEW

PRINCIPAL DATA ANALYZED

- NASA/HQ 5-YEAR PLAN
- MSFC MATERIALS PROCESSING DEVELOPMENT PLAN-PRELIMINARY (PARTIAL)
- TRW MATERIALS PROCESSING PAYLOADS – INPUTS BY BOB HAMMEL
  - PROCESS DEVELOPMENT EQUIPMENT
  - PRODUCTION MODULES
- GRUMMAN SPACE STATION STUDY
- RI SPACE INDUSTRIALIZATION STUDY
- MDAC SKYLAB REUSE STUDY
- MDAC COMMERCIAL SPACE MANUFACTURING STUDY
- DISCUSSIONS AT MSFC, 5 MAY 1978, AND FOLLOW-UP DATA

REVIEW CONCLUSIONS

- MOST PAYLOAD CONCEPTS PREVIOUSLY PLANNED FOR MAN-SUPPORT ON EARLY MISSIONS
- HQ AND MSFC NOW MOVING TOWARD EARLY FREE-FLYING AUTOMATED-PROCESS MODULES-TO DECREASE TOTAL COST PER EXPERIMENT
- MATERIALS PROCESSING PAYLOADS ARE KEY DRIVERS FOR POWER MODULE
  - HIGH POWER
  - LOW G
  - LONG DURATION

MPS PROGRAM OVERVIEW

- Meeting the first two goals are NASA responsibilities, while the second two goals are joint NASA/Industry responsibilities. In the latter cases, NASA provides the basic space facilities and cost effective accommodations Industry defines detailed experiments, products, and production systems and sponsors specific programs.

- Multiple investigations and experiments are needed to search for promising opportunities and to study the range of process control parameters in each area of investigation.

- Cost-effective experimentation is needed both to maximize scientific return and to encourage healthy participation by industry.

- Little specific definition is available beyond 1986, but a long-term developing program is envisioned due to:
  - Increasing complexity of experimentation
  - New avenues opening as knowledge increases
  - Growing needs and opportunities for new and improved products both on earth and in space

MPS PROGRAM OVERVIEW

GOALS

SCIENTIFIC INVESTIGATIONS – DEVELOP UNDERSTANDING OF FUNDAMENTAL PROCESSES AND PROPERTIES OF MATERIALS IN SPACE ENVIRONMENT

UTILITY DEMONSTRATIONS – DEMONSTRATE FEASIBILITY AND VALUE OF SPACE FOR ECONOMICALLY SOUND PRODUCT PRODUCTION

COMMERCIAL RESEARCH – INITIATE AND ENCOURAGE GROWTH IN USER-SPONSORED UTILIZATION OF SPACE FOR RESEARCH IN MATERIALS SCIENCE AND TECHNOLOGY

COMMERCIAL PRODUCTION – INITIATION AND GROWTH OF ORBITAL MANUFACTURING OPERATIONS

FEATURES

MULTIPLE INVESTIGATIONS; NUMEROUS OPERATIONS

- MANY OPPORTUNITIES TO INVESTIGATE
- AIMED AT COST-EFFECTIVE EXPERIMENTATION; MULTIPLE EXPERIMENTS PER FLIGHT

LONG-TERM, MULTIPLE-FLIGHT PROGRAM

- A VARIETY OF PROCESSING FACILITIES AND PAYLOAD CONFIGURATIONS
- MIX OF R&D AND APPLICATIONS
- INCREASING REQUIREMENTS FOR POWER AND TIME-IN-SPACE OVER THE YEARS

MPS PAYLOAD SCENARIO (TYPICAL)

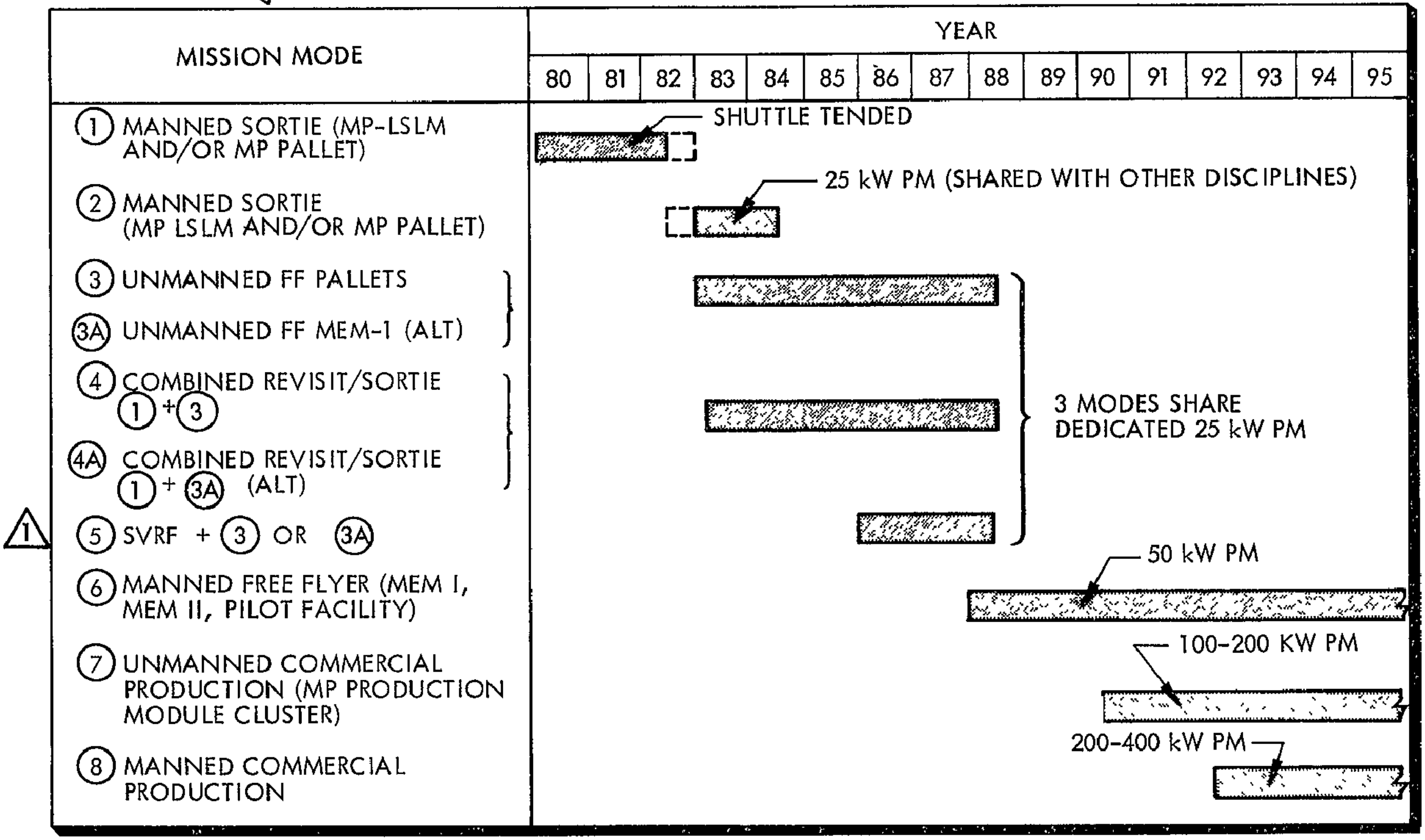
- Projections made in this study assume this scenario which shows the Power Module being used for MPS as soon as it can be made available:
  - Initial application would provide increased power and duration fo sortie missions.
  - As soon as unmanned free-flyer capability can be implemented (either configuration 3 or 3A) its capability can be utilized as a dedicated MPS Power Module.
  - Revisits to the free-flyer for experiment change-out can be combined with sortie missions to accomplish manned experimentation (4 or 4A).

- Starting in 1986, space vacuum research can be supported by the same MPS-dedicated Power Module (5).

- By 1988, MPS capability should be supported by man in space because of increased complexity of MPS payloads and to enable efficient production system development (6).

- Production facilities are expected to evolve in both unmanned and manned configurations for the most cost-effective accommodation of differing processes (7 and 8).

MPS PAYLOAD SCENARIO (TYPICAL)



1 SVRF = SPACE VACUUM RESEARCH FACILITY

MPS PROGRAM ELEMENTS AND CANDIDATE PROCESS FACILITIES

- This chart introduces the five major MPS program elements and identifies planned processing facilities.

- The first three elements dominate early requirements and were emphasized in this study. Initial versions of all process facilities for these three program elements will be used in the 1980 to 1982 period.

- Growth versions of the "vacuum mounted" units can be adapted for more automated operation on free-flyers. Continued use of processing facilities designed for pressurized environments is expected to support on-going man-tended experimentation. Additional facilities may emerge as more knowledge of the behavior of materials in space develops.

MPS PROGRAM ELEMENTS AND CANDIDATE PROCESSING FACILITIES

PROGRAM ELEMENTS		PROCESSING FACILITIES	INSTALLATION ENVIRONMENT
1. CRYSTAL GROWTH AND SOLIDIFICATION	△1	SES/FURNACE	VACUUM
		SES/FLOAT ZONE CRYSTAL GROWTH	VACUUM
	△2	MEA-II	VACUUM
	△3	FLUID EXPERIMENT SYSTEM	PRESSURIZED
		ANALYTICAL FLOAT ZONE	PRESSURIZED
2. CONTAINERLESS PROCESSING		SES/ACOUSTIC LEVITATION	VACUUM
		SES/ELECTROMAGNETIC LEVITATION	VACUUM
		SES/ELECTROSTATIC LEVITATION	VACUUM
3. FLUID AND CHEMICAL PROCESSES		BIOPROCESSING FACILITIES	PRESSURIZED
		FLUID EXPERIMENT SYSTEM	PRESSURIZED
		LATEX REACTOR SYSTEM	PRESSURIZED OR VACUUM
4. VACUUM RESEARCH		SPACE VACUUM RESEARCH FACILITY (SVRF)	
5. COMMERCIALIZATION		ANY OF THE ABOVE, OR NEW FACILITIES	

NOTES:

△1 SES = SOLIDIFICATION EXPERIMENT SYSTEM – A VERSATILE PROCESS SUPPORT AND CONTAINER SYSTEM NOW UNDER DEVELOPMENT (1980 IOC). ITS EVOLUTIONARY GROWTH CAN MAKE IT SUITABLE FOR FREE-FLYER OPERATIONS.

△2 MEA II = PLANNED GROWTH SYSTEM BASED ON THE MATERIALS EXPERIMENT ASSEMBLY (MEA) WHICH SUPPLIES SELF-CONTAINED SUPPORT FOR 4 MPS CANISTERS.

△3 FLUID EXPERIMENT SYSTEM (FES), ALSO REFERRED TO AS MULTIPURPOSE FLUID FACILITY; SCHEDULED FOR FLIGHT IN 1980.

ESTIMATED MPS ENERGY REQUIREMENTS

- These MPS experiment energy requirements are based on recent NASA projections for the "extended" case. Both processing power and direct processes support power are included (no power is included for man support or vehicle functions, such as attitude control and communications).

- In NASA projections, the "constrained" case limited power and time to STS sortie capabilities, the "unconstrained" case lifted these limitations but was limited to currently defined investigations, while the "extended" case projected additional new investigations, assuming the "unconstrained" power and time levels. The "extended" requirements are considered by NASA to be realistic for the experimental energy projections, while commercial projections may grow somewhat as they become more completely defined.

- This study concentrated on accommodation of the three areas listed under "experimental" since they dominate the currently estimated requirements and are more completely defined at this time. Vacuum Research, to be initiated in 1986, will require considerable energy, principally at relatively low power for long periods. It was considered separately in the study.

- Crystal Growth and Solidification, which requires between 87% and 92% of the total experimental energy requirements, nees multiple, simultaneous processing operations for its accommodation – a minimum of two facilities operating at a time – to maintain the total operating time per year within the constraints of a single Power Module operating time (see page 1B-12).

ESTIMATED MPS ENERGY REQUIREMENTS- kWh ⚠1

	1983	1984	1985	1986
EXPERIMENTAL				
• CRYSTAL GROWTH AND SOLIDIFICATION	76,200	102,700	94,600	107,600
• CONTAINERLESS PROCESSING	5,700	6,600	5,500	6,200
• FLUID AND CHEMICAL PROCESSES	5,500	4,200	3,200	3,100
	87,400	113,500	103,300	116.900
COMMERCIALIZATION	300	600	850	850
VACUUM RESEARCH				
UP TO 13,000 HR OF EXPERIMENTS @ 2 kW PLUS 96 HR OF BAKE-OUT @ 12 kW				27,000

CONCLUSION: CURRENTLY ESTIMATED ENERGY REQUIREMENTS ARE DOMINATED BY EXPERIMENTAL PROCESSING, ESPECIALLY CRYSTAL GROWTH AND SOLIDIFICATION

⚠1 NASA ESTIMATES ("EXTENDED" CASE)

MPS POWER AND TIME REQUIREMENTS

- All experimental processing, in 1983 through 1986, could be accommodated with 13.7 to 15.7 kW, if 10,000 to 13,000 hours per year of testing could be provided. The total testing time (sum of three cases) peaks at 18,000 hours (1984) and involves 800 experiments requiring from one hour to 120 hours each. The first set of data shows that a single set of equipment for each area of testing (program element) is insufficient since there are only 8,760 hours in a year of full-time testing.

- Duplication of all equipment (a total of six operational units), which is an initial possibility considered by NASA, shows a power requirement of 27.4 to 31.4 kW.

- An alternative approach is indicated by the third set of data, involving use of a minimum of four units in simultaneous operation. This does not increase maximum testing time over the previous case but reduces the power requirement estimates for 1983 through 1986 to a range from 20.8 to 24.8 kW. The time requirement is still dominated by Crystal Growth and Solidification with two units operating up to 280 days per year.

- Free-flyer operations appear to be the most economical method of accommodating long durations. Some sortie operations can be used to provide for those fluid and chemical processes which require manned attention.

MPS POWER AND TIME REQUIREMENTS ⚠1

EXPERIMENTAL PROCESSING – 1983 THROUGH 1986

		CRYSTAL GROWTH AND SOLIDIFICATION		CONTAINERLESS PROCESSING		FLUID AND CHEMICAL PROCESSES		TOTAL POWER (kW) ⚠2	MAXIMUM TIME (HR/YR)
		POWER (kW)	TIME (HR)	POWER (kW)	TIME (HR)	POWER (kW)	TIME (HR)		
SINGLE SET OF EQUIPMENT	1983	7.1	10,700	5.4	1,100	1.2	4,500	13.7	10,700
	1984	7.7	13,300	5.4	1,200	1.2	3,500	14.3	13,300
	1985	8.7	11,300	5.4	1,000	1.2	2,600	15.3	11,300
	1986	9.1	11,800	5.4	1,100	1.2	2,500	15.7	11,800
DUPLICATE OF ALL EQUIPMENT	1983	14.2	5,350	10.8	550	2.4	2,250	27.4	5,350
	1984	15.4	6,650	10.8	600	2.4	1,750	28.6	6,650
	1985	17.4	5,650	10.8	500	2.4	1,300	30.6	5,650
	1986	18.2	5,900	10.8	550	2.4	1,250	31.4	5,900
DUPLICATE CRYSTAL GROWTH AND SOLIDIFICATION EQUIP. ONLY	1983	14.2	5,350	5.4	1,100	1.2	4,500	20.8	5,350
	1984	15.4	6,650	5.4	1,200	1.2	3,500	22.0	6,650
	1985	17.4	5,650	5.4	1,000	1.2	2,600	24.0	5,650
	1986	18.2	5,900	5.4	1,100	1.2	2,500	24.8	5,900

⚠1 NASA ESTIMATES ("EXTENDED" CASE)

⚠2 POWER REQUIREMENTS CAN BE REDUCED SLIGHTLY BY SEQUENCING EXPERIMENTS – BASED ON TIME-LINE ANALYSIS WHEN SUFFICIENT DATA IS AVAILABLE

CONCLUSIONS: ACCOMMODATION OF FOUR OR MORE PROCESSING FACILITIES ON NEAR FULL-TIME BASIS MAY MEET POWER/TIME REQUIREMENTS THROUGH 1986 USING A DEDICATED 25 kW POWER MODULE

- MOSTLY AUTOMATED PROCESSING ON FREE-FLYER
- SORTIE MODE FOR SOME MANNED PROCESSING

MPS HARDWARE ELEMENTS

- This chart shows the variety of payload accommodation systems being considered for the near future and those envisioned beyond.

- Pressurized modules (initially the long spacelab module – LSLM) accommodate those Fluid and Chemical Process facilities which need direct manned attention plus command/control equipment for process facilities mounted in a vacuum environment on the same flight. The progression of pressurized modules includes

  - An MP Pressurized Module in the payload bay for sortie flights or, later, when a free-flyer is operational, for sortie/revisit flights.
  - Mem-II, a later manned free-flyer module
  - Manned production modules in the 1990s

- Accommodation systems to provide for process facilities mounted in a vacuum environment include

  - Pallets in the payload bay on sortie missions
  - Pallets or MEM-I on a free-flyer supported by the PM
  - A Vacuum Research Facility for high vacuum experimentation
  - Production facilities on unmanned or manned production clusters

- In general, considerably less power is required for the pressurized facilities than for the vacuum-mounted experiments.

MPS HARDWARE ELEMENTS

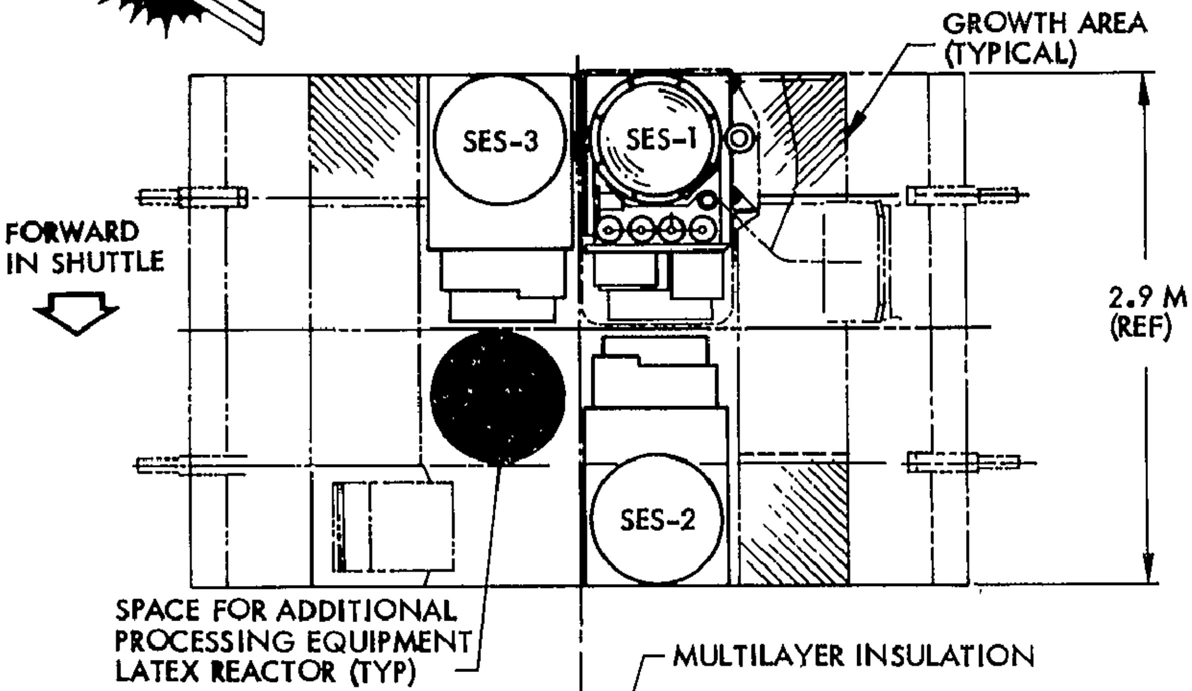
PAYLOAD ACCOMMODATION SYSTEM	PROCESSING FACILITIES		TIME PERIOD	AVERAGE EXPERIMENT POWER DESIRED (kW)
	PROCESS SUPPORT SYSTEM	PROCESS APPARATUS		
MP PRESSURIZED MODULE (LSLM)	• FLUID EXPERIMENT SYSTEM (FES) • BIOPROCESSING FACILITIES		1980-82	1.2 - 2
	• COMMAND/CONT FOR PALLET EQUIPMENT		1983-86	1.2 - 10
MP PALLET – SORTIE (CARGO BAY MOUNTED)	• SES (SOLIDIFICATION EXP SYST) • MEA (MAT'LS EXP ASSY) • MEA-II	• SAMPLE MAGAZINES • SES FURNACE • LEVITATION SYSTEMS (ACOUSTIC, EML, ESL)	1980-82	6.5 - 10
			1983-86	15 - 25
MP PALLET – FREE-FLYER MEM-I MATERIALS EXPERIMENT MODULE	• GROWTH VERSIONS OF ABOVE (MODIFIED FOR SPACE CHANGE-OUT AND INCREASED MISSION LIFE)	• GROWTH VERSIONS OF ABOVE (MODIFIED FOR MORE SAMPLES, SPACE CHANGE-OUT, AND INCREASED MISSION LIFE)	1983 TO 1988	25
SVRF (SPACE VACUUM RESEARCH FACILITY)	• HEMISPHERIC SHELL • EXTENSION BOOM • GIMBAL SYSTEM (IF REQD) • TWO MODIFIED PALLETS • HEAT REJECTION SYSTEM	• HIGH PURITY MAT'LS PROCESS EQUIPMENT	1986-?	2 kW OPERATING 12 kW BAKE-OUT
MEM-II (MANNED MP MODULE)	• PERSONNEL HABITAT • PRESSURIZED MP MODULE • GROWTH VERSIONS OF: FLUID EXP SYST AND BIO-PROCESSING FACILITIES • COMMAND/CONT. FOR VACUUM ENVIRONMENT PROCESSING EQUIPMENT		1988 ON	10 TO 20
PRODUCTION MODULES • AUTOMATED PROCESS CLUSTER	• SINGLE-PURPOSE PROCESS SUPPORT FACILITIES – CAN BE MODIFIED, OUTFITTED VERSIONS OF MEM-I	• DEDICATED PROCESS EQUIPMENT • MATERIALS/PRODUCT MAGAZINES	1990 ON	15-30 EACH 100 TO 400 GROUPED
• MANNED PROCESS CLUSTER	• MULTI-PURPOSE PRESSURIZED MODULE CONTAINING FLUID AND/OR BIOPROCESSING SYSTEMS WHICH REQUIRE MAN-TENDED OPERATIONS DERIVED FROM MEM-II			

TYPICAL MPS PALLET ARRANGEMENT

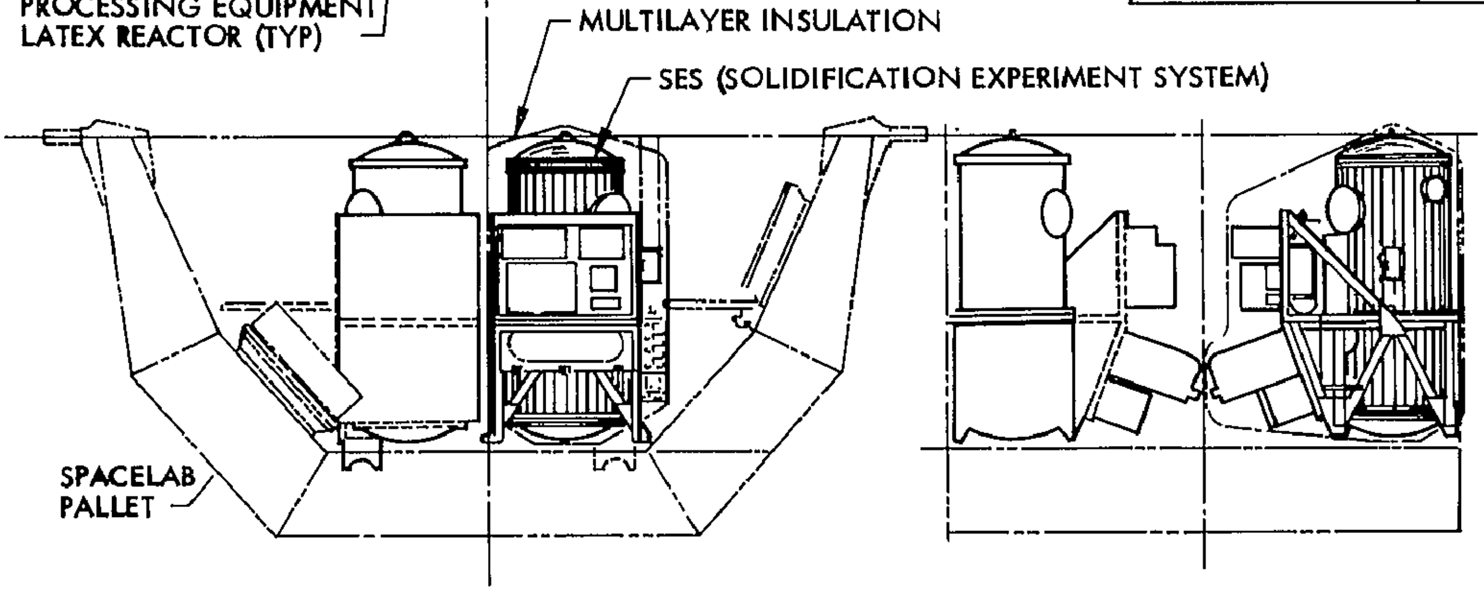
- A typical accommodation of four process units on a pallet is shown here. There are three SES units which would typically contain apparatus for two Crystal Growth and Solidification investigation and one Containerless Process investigation. Space is available for an additional facility such as a latex reactor, an MEA, or an MEA-II.

- Pallet accommodation may be used in two ways
  - It is planned for early sortie flights for 1980 through 1982, limited to about 3,000 kg load on each pallet
  - It could be modified for use in the free-flyer mode, supported by a Power Module. Experiment facility weights would increase to provide for more test samples and on-orbit change-out. Pallet structure would be strengthened, additional thermal control systems provided, and a docking adapter added.

TYPICAL MPS PALLET ARRANGEMENT



WEIGHT SUMMARY (KG)		
ITEM	SORTIE	FREE-FLYER
EXPERIMENT FACILITIES (4)	2,400	3,000
SUPPORT SUBSY	600	900
PALLET STRUCTURE	500	700
THERMAL PROTECTION & RADIATOR	NA	500
DOCKING ADAPTER	NA	500
TOTAL	3,500	5,600



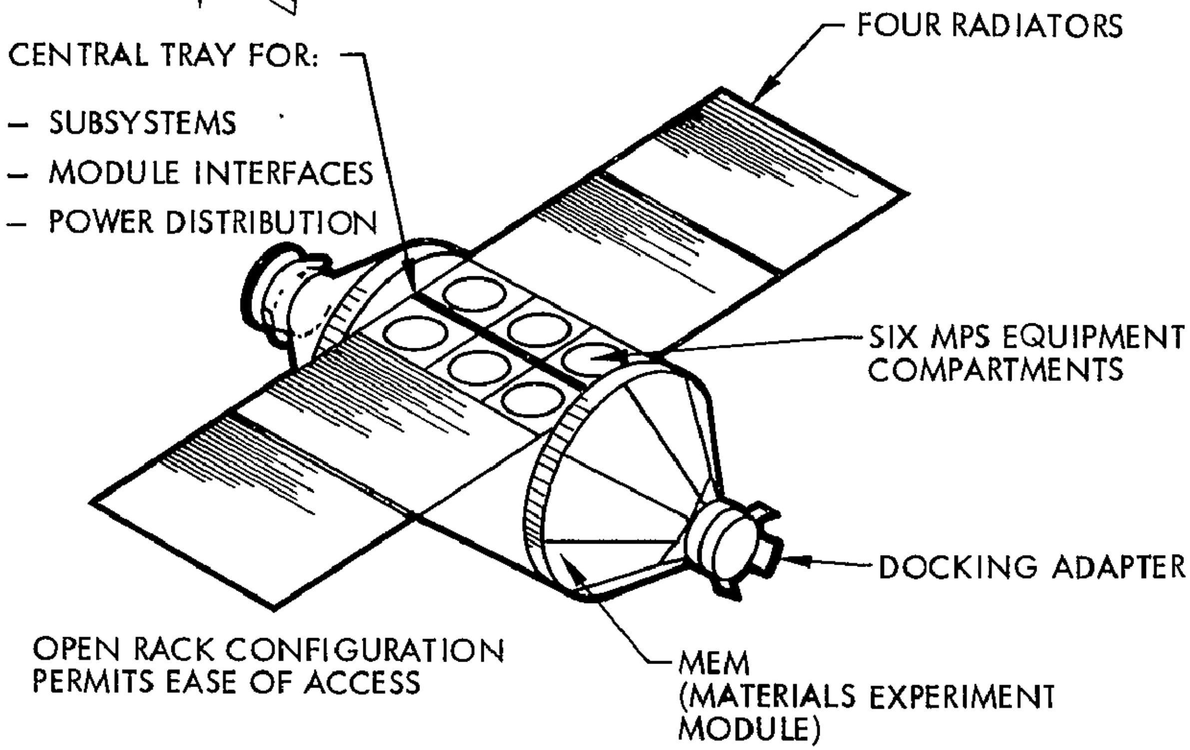
MEM-I (MATERIALS EXPERIMENT MODULE)

- MEM-I is an alternative concept for accommodation of MPS payloads in the free-flyer mode. It would be designed specifically for efficient accommodation of MPS experimentation. As initially conceived, it would provide six compartments, each about 1.5 x 1.5 x 3 meters deep.

- Ease of access for on-orbit change-out and maintenance would be a major design requirement. Thermal control systems would be primarily integral with the MEM-I, but the PM could provide cooling for the lower-temperature equipment. Docking adapters at each end would provide configuration flexibility. This concept has considerable growth potential for MPS experimentation in more advanced configurations and potentially for materials production systems.

- Trade-offs of the effectiveness of this approach compared to the pallet approach are underway in NASA, including a "Mini-MEM" concept for early deployment.

MEM-I (MATERIALS EXPERIMENT MODULE)



TYPICAL EXPERIMENTS PRODUCT DEMONSTRATIONS
• SEMICONDUCTOR CRYSTALS
• DETERMINATION OF SINGLE CRYSTAL SIZES, AND QUALITY LIMITS
• IR DETECTORS
• LASER FUSION TARGETS
• IMPROVED LASER OPTICAL GLASSES
• IMPROVED FIBER OPTICS
• HIGH-TEMPERATURE METALS
• NEW AND IMPROVED MEDICAL PRODUCTS
• MONODISPERSED LATEX

ELEMENT	WEIGHT (kG)	POWER (kW)
• EXPERIMENT FACILITIES (6)	4,500	25
• SUPPORT SUBSYSTEMS	700	3
• STRUCTURE AND RADIATORS	3,000	–
TOTAL	8,200	28

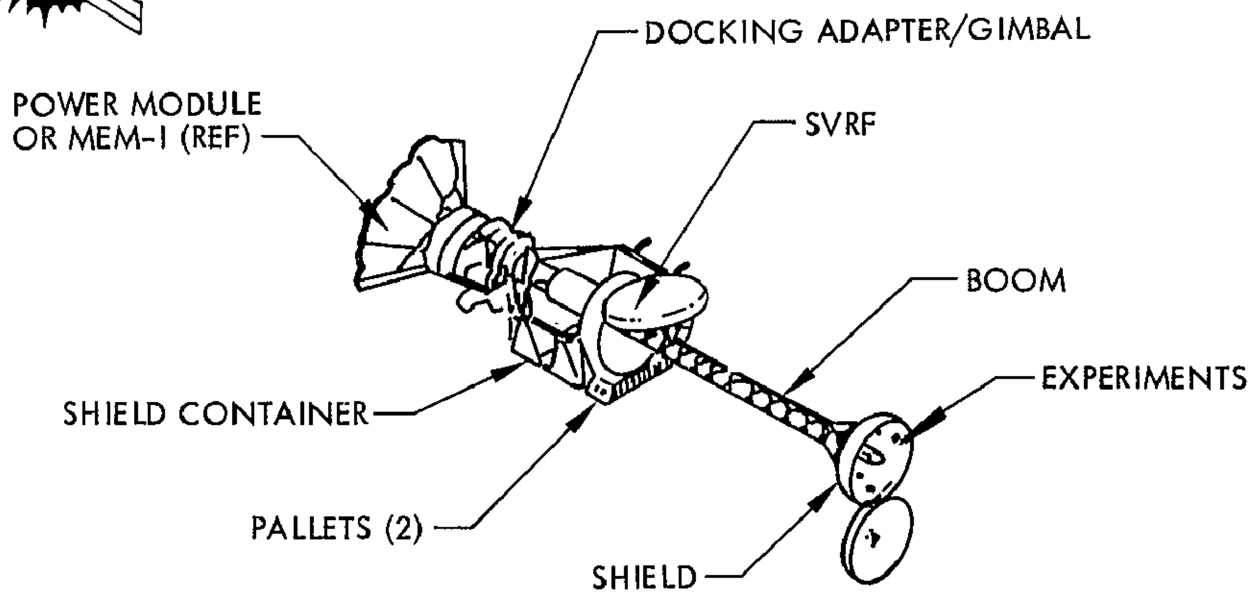
SVRF (SPACE VACUUM RESEARCH FACILITY)

- A hemispherical shield oriented with its open end opposite to the direction of flight produces a high vacuum. Pumping rates are much higher than currently obtained on earth and a vacuum of less the 10^{-14} Torr is predicted ($<10^6$ molecules per cm^2-sec).

- Both new scientific knowledge and potential new products are expected, including: (1) surface physics/chemistry, current knowledge of which is limited by gas molecule deposits, (2) thin film solar cells, and (3) metals purification.

- Mounting at rear of PM/MEM-I is compatible from power usage considerations. During high-power bake-out, MEM-I can be partially powered down for a few hours at a time. Potential contamination from MEM-I out-flow requires investigation.

SVRF (SPACE VACUUM RESEARCH FACILITY)



ELEMENT	WEIGHT (KG)
• SHIELD AND BOOM	2,000
• SVRF SUPPORT SYSTEM	4,500
• MODIFIED PALLETS (2)	3,200
• EXPERIMENTS	900
TOTAL	10,600

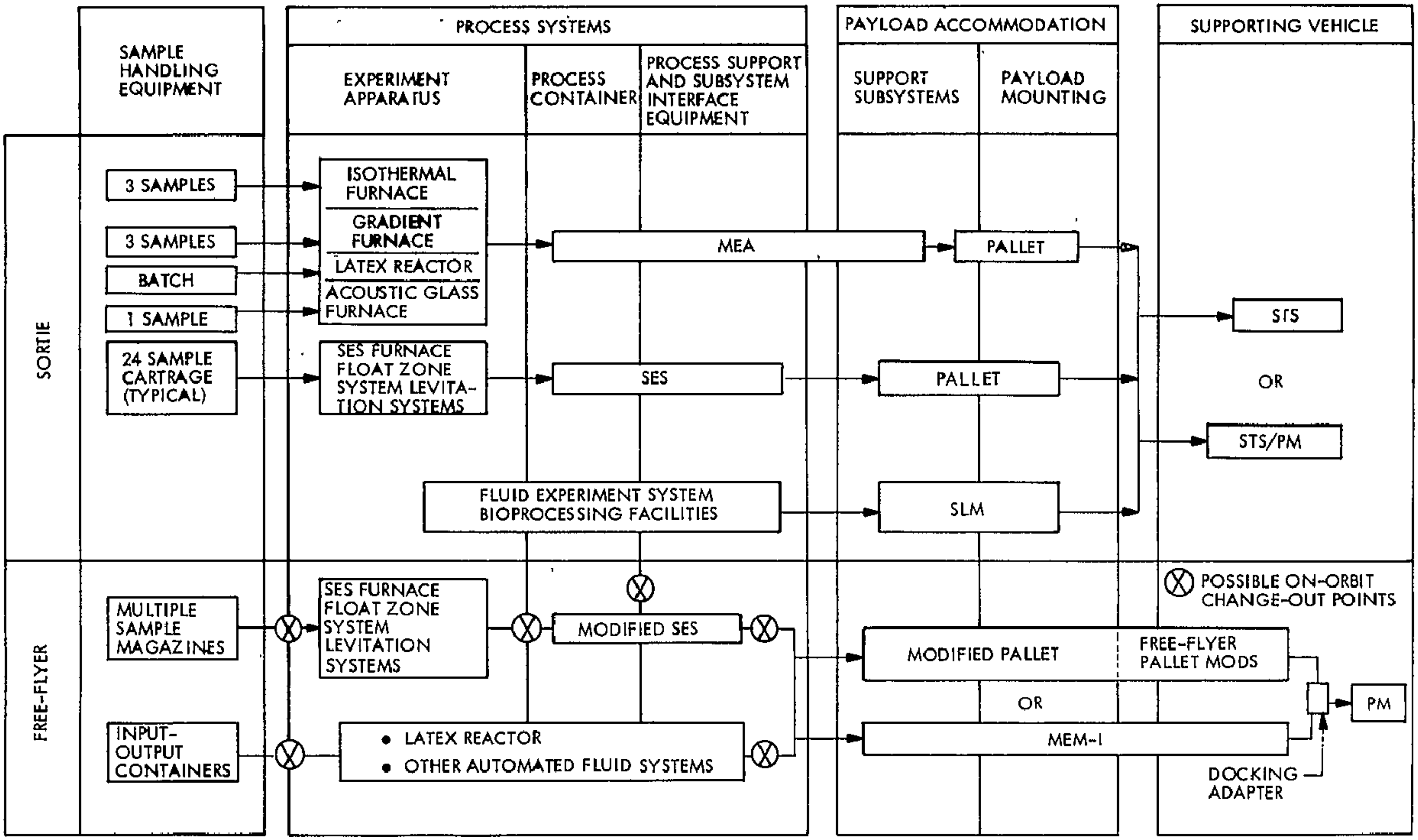
OPERATION	POWER (kW)
• BAKE-OUT (~100 HR/YR)	12
• EXPERIMENT OPERATION (NEAR CONTINUOUS)	2
• SUPPORT SUBSYSTEMS	1
EXP. OPERATIONS TOTAL	3

MPS HARDWARE INTERFACES

- Sortie mission experiment accommodations involve slightly different interfacing arrangements, depending upon the process facilities employed:
  - MEA incorporates most of its own support subsystem functions but its samples use separate furnace chambers and are currently limited in number
  - SES relies more heavily on pallet supplied services but incorporates more sophisticated sample change-out in space or apparatus change-out on the ground
  - Fluid and Bioprocessing in the spacelab module use largely integral processing systems designed for man-tending (latex reactor is an exception because it can be remotely controlled and vacuum mounted)

- Modification for free-flyer accommodations include:
  - Increased, automated sample change-out capability
  - A number of on-orbit equipment change-out interfaces
  - Either a modified pallet or a new system (MEM-I) to provide a portion of the supporting vehicle functions as well as support subsystem and payload mounting functions

MPS HARDWARE INTERFACES



MPS PALLET FLIGHT CONFIGURATIONS

- A free-flyer pallet system could use one pallet for MPS processing facilities and another for support subsystems. It would be operated almost continuously except during revisits.

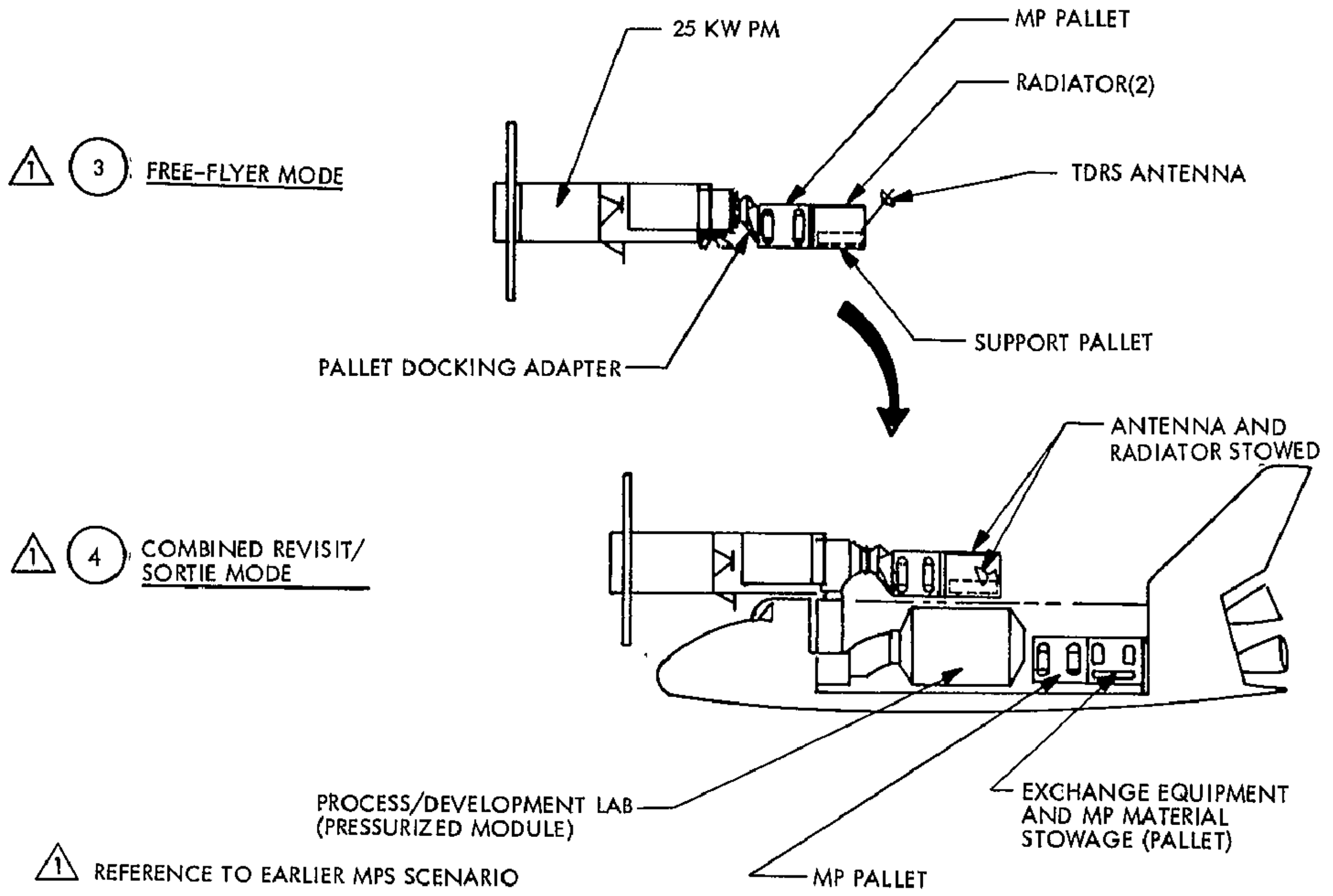
- A combined revisit and sortie mission mode can serve both change-out and check-out functions for the free-flyer and provide time and power for additional MPS experimentation. A 25 kW PM plus the Orbiter could supply up to 27 kW experiment power for a seven-day mission, i.e., 25 (from PM) and 7 (from Orbiter) -5 (for LSLM) = 27 kW. One flight each two months (seven days each) would provide 42 days per year (over 1000 hours) of man-tended experimentation; with some duplication of pressurized process equipment, this appears adequate. Short-term investigations with STS pallet equipment is also possible. Free-flyer equipment would be operated for check-out only (heat rejection by free-flyer radiators may have to be limited to avoid thermal interference with Orbiter radiators).

MEM-I FLIGHT CONFIGURATIONS

- This is a preliminary concept for the MEM-I flight configurations. Its operations would be similar to those described for the pallet free-flyer discussed on the previous chart. It could provide more testing capability than the pallet system, potentially reducing the number of revisits required.

- Later addition of a second MEM-I to the configuration could further reduce revisit requirements. Reduction to about three revisits per year would be desirable to assist in meeting the NASA goal of minimum cost per experiment. Two modules could support a full range of facility types with no on-orbit equipment change- out, except for maintenance and updating. Manual experimentation could still be adequate by extension of visit times to 15 or 20 days.

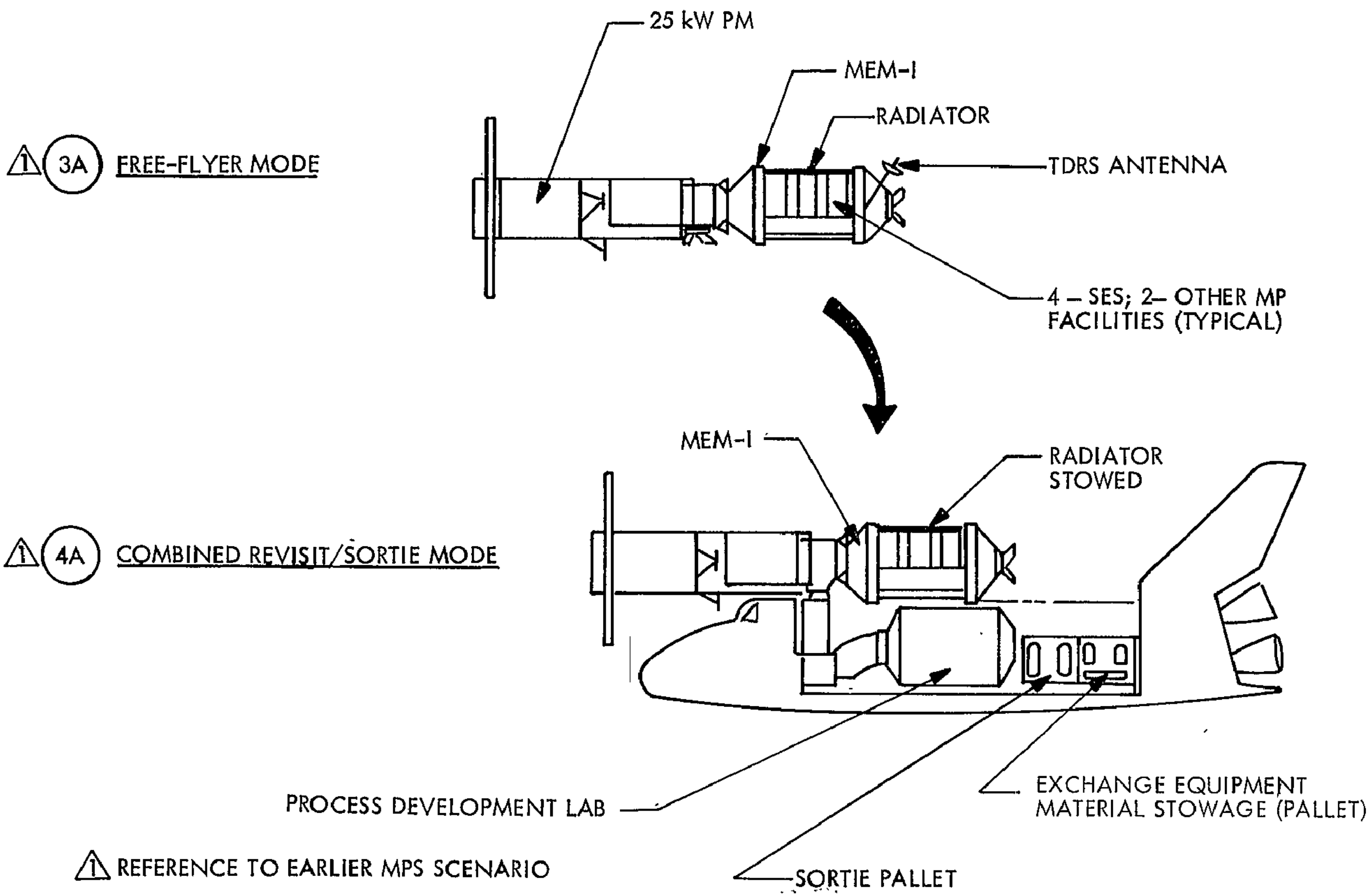
MPS PALLET FLIGHT CONFIGURATIONS



△1 REFERENCE TO EARLIER MPS SCENARIO

MEM-I FLIGHT CONFIGURATIONS

(ALTERNATIVE TO MPS PALLETS)



1 REFERENCE TO EARLIER MPS SCENARIO

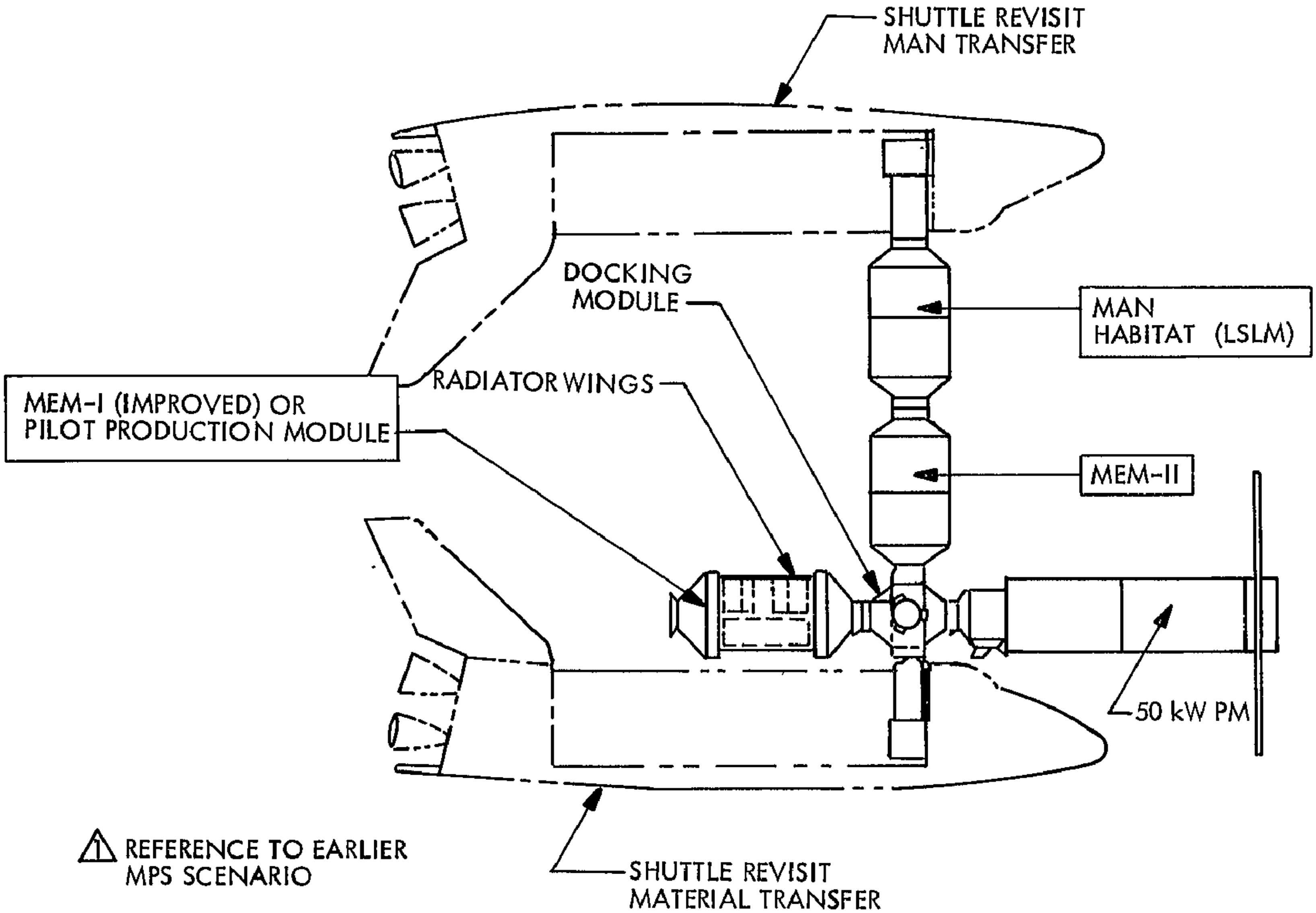
ADVANCED MPS DEVELOPMENT CLUSTER

- By about 1988, after five years of primarily unmanned experimentation, a manned system is envisioned. Sophisticated experimentation can be carried out with more direct manned attention and tuning of production concepts (pilot production) can be accomplished efficiently.

- A 50 kW Power Module appears adequate, providing
  - 10 kW for support of a four-man habitat
  - perhaps 7 k to support the subsystems of the MEM-II (workshop module)
  - 30 to 35 kW available for experiments and/or pilot production operations

ADVANCED MPS DEVELOPMENT CLUSTER

⚠ (6) MANNED FREE-FLYER MODE



⚠ REFERENCE TO EARLIER
MPS SCENARIO

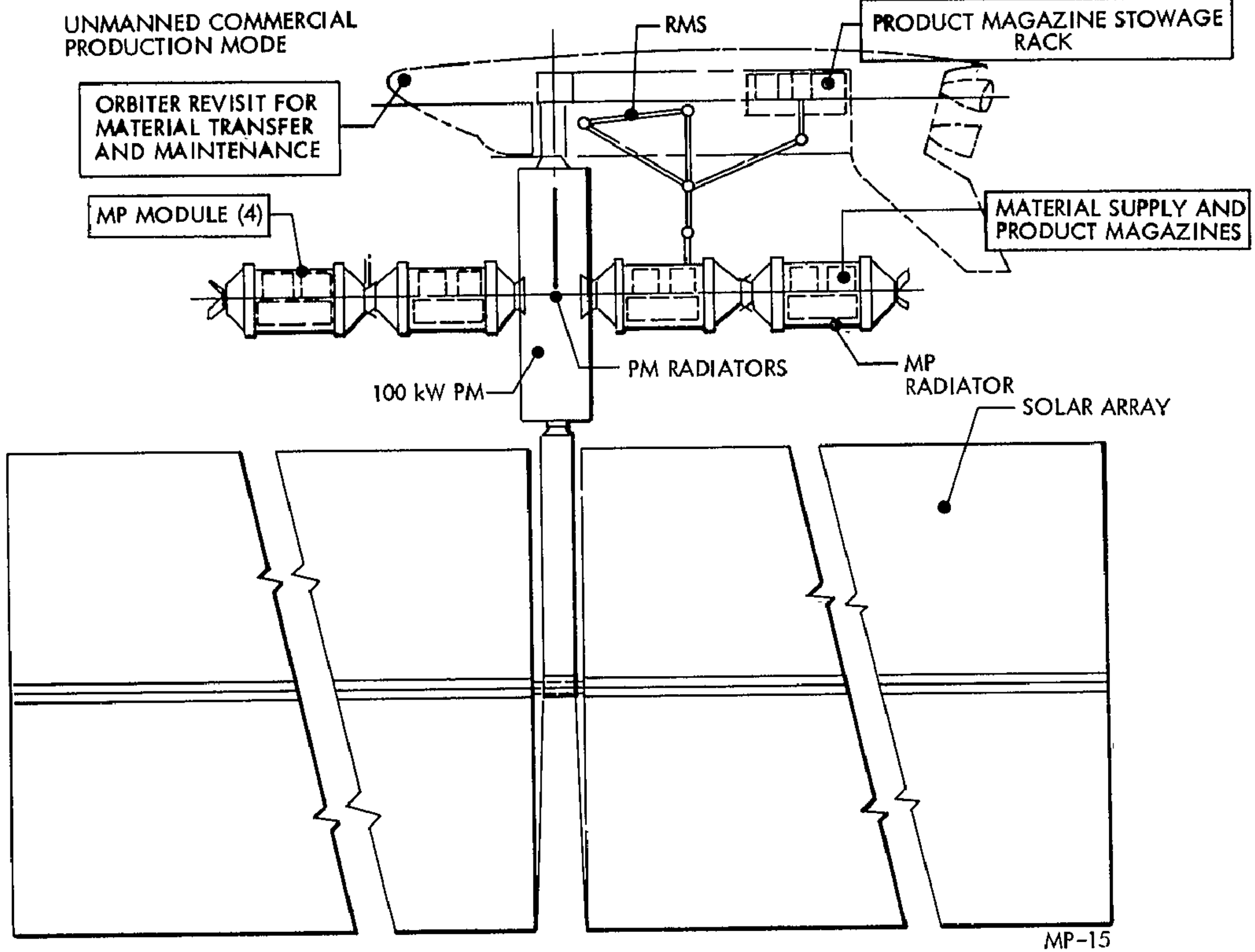
MPS UNMANNED PRODUCTION CLUSTER

- Four dedicated production modules are shown clustered, envisioning an IOC of about 1990. Each contains its process facility plus material input and product output magazines. This concept applies maximum use of MEM-I hardware designs. Common use of Power Module support and shared revisits for four production units aids cost-effective production.

- Initial production clusters may require a 100 kW Power Module, each dedicated production module being projected to require 15 to 30 kW. Later unmanned clusters may use 100 to 200 kW total.

- Manned production clusters for later in the 1990s may require 200 to 400 kW. More automated units will justify the costs and allow more real-time maintenance. Man-tended processes can also be accommodated efficiently when personnel are used for multiple functions, including maintenance of automated production units in the same cluster.

MPS UNMANNED PRODUCTION CLUSTER



POWER AND DURATION REQUIREMENTS OF MPS FLIGHT SYSTEMS

- In 1982, the STS falls short of meeting energy requirements for MPS experimentation. It is marginal on power for typical pallet configurations (to obtain needed power, current plans are to fly pallet missions jointly with a deployable spacecraft, not employing the LSLM on these flights). More clearly, it falls short of desired duration even assuming a seven-day MPS flight every two months or more often. If available in 1982, a Power Module could be used effectively to support MPS sortie flights.

- In the 1983 to 1986 period, even the addition of a 25 kW PM fails to meet projected MPS needs using the sortie mode alone, especially if the need for cost effectiveness is included. Even providing a Power Module with appreciably more than 25 kW (about 11 kW for experiments) would not satisfy duration requirements unless an orbiter is employed approximately 9 months per year for MPS testing.

- An unmanned free-flyer with a 25 kW Power Module provides a good match to MPS requirements for 1983 through 1986. In the free-flyer mode, the total power supplied should exceed 25 kW by optimizing the orbit and vehicle attitude. Even with no operation of free-flyer process equipment during 42 days of revisit, there is a comfortable duration margin.

- The chart also summarizes projections for advanced experimental and production configurations.

POWER AND DURATION REQUIREMENTS FOR MPS FLIGHT SYSTEMS

CONFIGURATION		MODE	CRITICAL OPERATIONAL PERIOD	PROCESSING POWER (kW) AVAILABLE/DESIRED	DURATION (DAYS PER YEAR) AVAILABLE/DESIRED
ORBITER	LSLM	SORTIE	1980-1982	2/1.2-2	42 /112 ⚠1
	PALLET			7/6.5-10	
ORBITER/25 kW PM	LSLM	SORTIE	1983-1986	6/1.2-10	120/280 ⚠2
	PALLET			11/15-25	
25 kW PM/MODIFIED PALLETS OR 25 kW PM/MEM-I		UNMANNED FREE-FLYER	1983-1986	30/25	323/280 ⚠3
50 kW PM/HABITAT/MEM-II/ MEM-I (OR PILOT PROD FAC)		MANNED FREE-FLYER	1988	50 TOTAL 30-35 PROCESSING	365
100 + kW PM/PRODUCTION FACILITY		• UNMANNED FF	1990 (?)	100 TO 200	365
		• MANNED FF	1992 (?)	200 TO 400	365

⚠1 42 DAYS/YEAR ASSUMES SIX 7-DAY MISSIONS

⚠2 120 DAYS/YEAR ASSUMES FOUR 30-DAY MISSIONS

⚠3 323 DAYS/YEAR IS 365 DAYS LESS SIX 7-DAY VISITS

MPS PAYLOAD REQUIREMENTS SUMMARY

- Payload requirements are summarized, emphasizing the 1983 through 1986 time period.
- Acceleration level, power and time (duration) requirements dominate the Power Module design requirements for MPS support.
  - Current plans contemplate that levitation systems will be required to operate up to 10^{-4} G on a short transient basis, but this is considered a compromise to allow for accommodation on the Orbiter considering both RCS actions and personnel movements. Power Module attitude control should be designed for 10^{-5} G at the experiments.
  - The slow growth of power requirements indicates that the 25 kW Power Module baseline, which should be optimized to provide somewhat more than 25 kW for the dedicated MPS application, may be adequate until a manned free-flyer is implemented.
  - Durations of up to 9 months/year indicate an early need to implement the free-flyer concept.
- Heat rejection (assuming here that 90 percent of power supplied to the unmanned free-flyer must be actively rejected) may be nearly all supplied by payload-peculiar systems. More detail of payload system design and accommodation design is required to define this area. For larger systems, 1988 and subsequent, an assumption of 80 percent was made for percentage of heat rejection; primarily on the basis of use of a manned-habitat systems. For example, the 50 kW power estimated for 1988 results in heat rejection of about 40 kW (both are estimated values).

MPS PAYLOAD REQUIREMENTS SUMMARY

	1983	1984	1985	1986	1988	1992
ACCELERATION LEVEL (G)	$<10^{-5}$	$<10^{-5}$	$<10^{-5}$	$<10^{-5}$		
ACCELERATION MIN DURATION (HR)	120	50	100	100		
ANGULAR ROTATION (REV/HR)	≤ 1	≤ 1	≤ 1	≤ 1		
CONTAMINATION – SVRF (MOLECULES/(CM^2/SEC)				10^6	TBD	TBD
DATA RATES – DIGITAL (KB/S)	10.0	7.5	9.5	8.0		
ANALOG DATA BANDWIDTH (MHz)	4.0	4.0	4.0	4.0		
POWER (kW)	20.8	22.0	24.0	24.8	50 (EST)	100-400 (EST)
ACTIVE HEAT REJECTION (kW)	18	20	22	23	40 (EST)	TBD
TIME (HR/YEAR)	5400	6700	5700	5900	CON-TINUOUS	CON-TINUOUS

NOTE: NO REQUIREMENT LIMITING ORBIT INCLINATION NOR PAYLOAD ORIENTATION, EXCEPT THAT SVRF MUST BE ORIENTED ALONG THE DIRECTION OF FLIGHT

MPS PAYLOAD CONCLUSIONS

- The first two conclusions covering 1982 through 1986, are considered well supported by available data.

- Projections beyond 1986 (conclusion No. 3), are not as well supported but are considered reasonable estimates for projecting Power Module evolution.

- The impact of the other critical requirements can only be defined through system design of complete configurations. However no serious difficulties are foreseen, only the need to optimize design approaches.

MPS PAYLOAD CONCLUSIONS

1.	POWER AND DURATION REQUIREMENTS FOR 1982 AND BEYOND EXCEED ORBITER/SPACELAB CAPABILITIES (WITHOUT POWER MODULE)
2.	THE POWER MODULE CAN BE PUT TO USE AS SOON AS IT CAN BE MADE AVAILABLE • DEFINABLE MPS DURATION REQUIREMENTS FOR 1983 AND BEYOND EXCEED ORBITER/SPACELAB/PM CAPABILITIES • A DEDICATED PM-WITH 25 kW CAPABILITY – COULD BE USED TO MEET MP REQUIREMENTS FOR 1983 THROUGH 1986 WITH DUAL-MODE OPERATION – FREE-FLYER IN NEARLY FULL-TIME OPERATION FOR AUTOMATED PROCESSING; REVISITED AT 2 TO 3 MONTH INTERVALS FOR TEST MATERIAL AND PROCESS EQUIPMENT CHANGEOUT – SORTIE-MODE OPERATIONS FOR EXPERIMENTS REQUIRING MANNED ATTENTION; CAN BE COMBINED WITH REVISITS TO FREE-FLYER
3.	MP POWER REQUIREMENTS BEYOND 1986 CAN BE EXPECTED TO RISE ABOVE 25 kW PM CAPABILITIES • APPROXIMATELY 50 kW BY ABOUT 1988 • 100 TO 200 kW IN ABOUT 1990 • 200 TO 400 kW IN THE 1990s
4.	OTHER CRITICAL MPS REQUIREMENTS ARE: • ACTIVE HEAT REJECTION OF MOST OF THE POWER SUPPLIED • GRAVITY LEVEL NOT EXCEEDING 10^{-5} G • ROTATION RATE NOT EXCEEDING ONE REV/HR

PUBLIC SERVICES (COMMUNICATION /NAVIGATION) PAYLOADS

- DATA REVIEW
- PROGRAM OVERVIEW
- TYPICAL POWER MODULE OPPORTUNITIES
- TYPICAL CONFIGURATIONS AND SCENARIOS
- POWER MODULE REQUIREMENTS

PS DATA REVIEW

- Many studies have been conducted in the area of Public Services initiatives for the 1980s and into the 1990s. Current studies lead by MSFC are typical and represent current thinking.

- Public Services initiatives using space systems involve predictable possibilities for industrial exploitation. Space supported communication and navigation systems are in operation allowing realistic projections of their growth. New technologies will require NASA sponsored development to encourage healthy growth.

- Concepts for implementation of projected growth have wide diversity. Some use platforms, others large single antennas. System sizing shows a wide range of possibilities.

- The common elements of geosynchronous operations and large multi-beam antennas allows choice of a few typical cases to project Power Module evolutionary growth requirements.

PUBLIC SERVICES DATA REVIEW

PRINCIPAL DATA SOURCES

- NASA/HQ 5-YEAR PLAN
- MSFC GEOSTATIONARY PLATFORM CONCEPT
- HQ SWITCHBOARD IN THE SKY REPORT
- ORBITAL ANTENNA FARMS – COMSAT LABORATORIES CONCEPT
- ADVANCED SPACE CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (AEROSPACE)
- JPL COMMUNICATION SYSTEMS STUDY
- RI SPACE INDUSTRIALIZATION STUDIES
- SAI SPACE INDUSTRIALIZATION STUDIES
- GRUMMAN SPACE STATION STUDY
- MDAC INFORMATION SERVICES AT GEO STUDY
- AEROSPACE INITIATIVES DEFINITION AND EVALUATION STUDY
- CONTACTS WITH MSFC PERSONNEL, 5 MAY 1978, AND FOLLOW-UP DISCUSSIONS

  DON SAXTON – COMMUNICATIONS INITIATIVES (AEROSPACE STUDIES)

  TED CAREY – GEOSTATIONARY PLATFORM

  CLAY HAMILTON

REVIEW CONCLUSIONS

- PUBLIC SERVICE INITIATIVES INCLUDE A NUMBER OF DEMONSTRABLE, ECONOMICALLY REWARDING OPPORTUNITIES
- STUDIES COVER WIDE RANGE OF POSSIBLE SIZES, CONFIGURATIONS, POWER REQUIREMENTS
  - ALL USE UNMANNED FREE-FLYERS IN GEOSYNCHRONOUS ORBITS
  - NEARLY ALL USE LARGE, MULTI-BEAM ANTENNAS
- SPECIFIC POWER MODULE OPPORTUNITIES EXIST FOR SEVERAL CASES

PUBLIC SERVICES PROGRAM OVERVIEW

- All proposed Public Service initiatives relate to the exploitation of "complexity inversion," the idea of placing large complex facilities in space (geosynchronous orbit) in order to allow major reductions in User requirements and equipment on the ground (by simplification).

- Multiple narrow beams from large antennas are central to the idea of frequency reuse factors of 100 to 1000 (depending on system sizing), high-gain/low-power systems, and a few satellites serving many users.

- Large linear arrays have also been proposed to provide navigation/locator systems with low cost passive ground units.

PUBLIC SERVICES PROGRAM OVERVIEW

OBJECTIVES

EXPLOIT:
- SHUTTLE PAYLOAD CAPABILITY
- IN-SPACE CONSTRUCTION
- ADVANCED ELECTRONICS/ANTENNA TECHNIQUES
- CONCEPT OF "COMPLEXITY INVERSION"

TO PROVIDE:
- COST SAVINGS FOR CURRENT COMMUNICATION SERVICES
- IMPROVED, EXPANDED AND MORE COST EFFECTIVE COMMUNICATION AND NAVIGATION SERVICES
- MORE EFFECTIVE USE OF FREQUENCY SPECTRUM AND GEO LOCATIONS
- SMALL SIZE, LOW-POWER USER EQUIPMENT REQUIREMENTS

WITH SERVICES INCLUDING:
- CURRENT SERVICES PROVIDED BY FEWER SATELLITES
- IMPROVED FIXED (POINT-TO-POINT) COMMUNICATIONS
- MOBILE COMMUNICATIONS
- EDUCATIONAL TV
- WIDEBAND DATA
- NAVIGATION/LOCATOR SYSTEMS

METHODS

- GEOSTATIONARY PLATFORMS
- LARGE MULTI-BEAM COMMUNICATION ANTENNAS
- ON-ORBIT TRAFFIC SWITCHING AND DATA HANDLING
- LARGE CROSSED (LINEAR ARRAY) NAVIGATION/LOCATOR ANTENNAS

TYPICAL PUBLIC SERVICE CATEGORIES

- This chart summarizes some of the specific services that are projected for the categories studied and identifies major system characteristics.

- It was concluded that five categories show significant power module opportunities. The wideband data case reviewed, typified by Electronic Mail, showed low power levels in space except for teleconferencing; the latter could require up to 220 kW.

- Each of four categories was studied separately:

  - Improved Current Services provided by a Geostationary Platform mounting a variety of communication systems plus geostationary earth observation sensors

  - Educational TV and Advanced Mobile Communications, each as a large multi-beam antenna system

  - Navigator/locator system as an example of large, precision structure for space assembly and test

TYPICAL PUBLIC SERVICES CATEGORIES

	IMPROVED LOWER-COST CURRENT SERVICES (1986)	EDUCATIONAL TELEVISION (1988)	WIDEBAND DATA (NEW EXPANDED) (1988)	ADVANCED MOBILE COMMUNICATIONS (1990)	NAVIGATION/ LOCATOR SYSTEM (1990s)
SERVICES	• TELEPHONE • TELEVISION • COMPUTER DATA • MARINE COMMUNICATIONS • AIRCRAFT COMMUNICATIONS • SEARCH/RESCUE COMMUNICATIONS	• SCHOOL DISTRICT PROGRAMMING • OPEN UNIVERSITY • MIGRANT WORKER EDUCATION • HANDICAPPED EDUCATION • PUBLIC/ADULT EDUCATION	• ELECTRONIC MAIL • COMPUTER DATA • TELECONFERENCE	• PERSONAL COMMUNICATION/ WRIST RADIO • LAW ENFORCEMENT • EMERGENCY COMMUN • SEARCH AND RESCUE	• SHIPS AND BOATS • AIRCRAFT • LAND VEHICLES • SEARCH AND RESCUE • HIKERS, HUNTERS, CAMPERS, ETC • PACKAGE LOCATOR
CHARACTERISTICS	FEWER SATELLITES VASTLY IMPROVED FREQUENCY REUSE SMALLER GROUND ANTENNAS LOWER GROUND POWER	1M FIXED ROOFTOP ANTENNAS (RECEIVE) 2M FIXED ANTENNAS (TRANSMIT) LOWER POWER GROUND TRANSMISSION ($\sim$60 W)	1M GROUND ANTENNAS LOW GROUND POWER ($\simeq$6 W FOR ELECTRONIC MAIL UP TO 40 KBPS)	OMNI-DIRECTIONAL GROUND ANTENNAS VERY LOW GROUND POWER ($\sim$ 1/4 W) MILLIONS OF USERS	• POCKET OR WRIST USER EQUIPMENT • PASSIVE USER SYSTEMS

TYPICAL PM OPPORTUNITIES IN PUBLIC SERVICES

- The principal Public Services needs for a Power Module begin in 1986. The first use is to support assembly and test operations in LEO, the PM being needed primarily to support duration requirements. Then by late 1986, dedicated deployment in GEO of a modified Power Module is required.

- Growth of power level is rapid for GEO operations
  - 65 kW by 1988
  - 270 kW by 1990

- Since the Navigation/Locator system is not a power-level driver and its definition is unclear at this time, further study of this concept was not carried out. Its assembly and test appears to require extensive operations, not only in LEO but probably also in GEO due to its large size and high level of precision.

- The first three cases listed in the chart were given further study and their configuration and development scenarios are reviewed in the following charts.

TYPICAL PM OPPORTUNITIES IN PUBLIC SERVICES

MAJOR HARDWARE	SUPPORT OF LEO ASSEMBLY AND TEST			MODIFIED PM FOR GEO OPERATIONS	
	POWER ⚠1 (kW)	DURATION (DAYS)	DATE	POWER (kW)	IOC
GEOSTATIONARY PLATFORM (80-METER, MULTI-ANTENNA PLATFORM)	3-5	$\boxed{40-60}$	1986	$\boxed{20-40}$	1986
EDUCATIONAL TV SATELLITE (9.5-METER DIAMETER MULTI-BEAM LENS)	3-5	$\boxed{\sim 180}$	1986	$\boxed{\sim 65}$	1988
PERSONAL/EMERGENCY COMMUNICATIONS SATELLITE (67-METER DIAMETER MULTI-BEAM LENS)	10-20	$\boxed{\sim 180}$	1988	$\boxed{\sim 270}$	1990
NAVIGATION/LOCATOR SYSTEM (2KM LONG LINEAR ARRAYS)	5-10	$\boxed{\sim 180}$	1990+	2 kW	1990+

$\boxed{}$ = POWER MODULE REQUIREMENTS DRIVERS

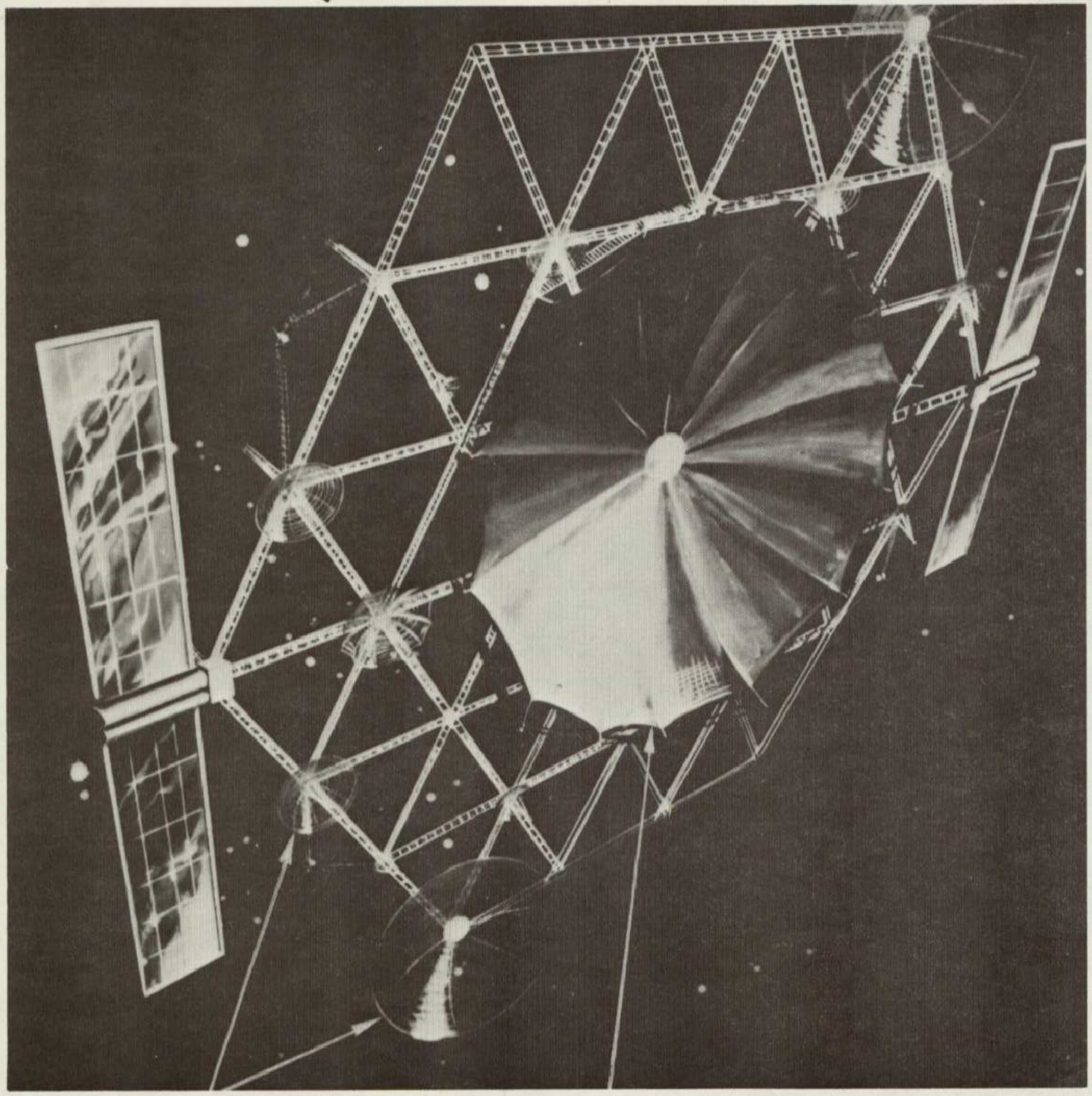
⚠1 EXCLUDES POWER FOR MAN SUPPORT (ORBITER/LSLM OR PERMANENT HABITAT)

GEOSTATIONARY PLATFORM

- The concept shown is as conceived initially by NASA but its solar power system and attitude control could be replaced by a modified, dedicated power module, tailored for GEO operations. Design and cost trades are required to establish the best approach for adapting power module technology for GEO operations such as this and other Public Service satellites.

- The platform, its support subsystem, and the 30-meter multibeam antenna system are proposed for NASA implementation. The other units (antennas, electronics, and sensors) would be supplied and operated by other Governmental and commercial users. The platform would be oriented with 0.5 deg accuracy; Users requiring greater accuracy would supply appropriate gimbal systems.

GEOSTATIONARY PLATFORM (GP)



MULTIPLE USER ANTENNAS AND SENSORS ⚠2

30 M MULTI-BEAM ANTENNA

CHARACTERISTICS	
DIMENSIONS: 40M X 80M	
POWER: 20 TO 40 kW	
POINTING: 0.5 DEG	
IOC DATE: 1986	
WEIGHT (KG) (MSFC ESTIMATES)	
– PAYLOADS	2600
– STRUCTURE	2850
⚠1 – SUPPORT SUBSYSTEMS	2750
TOTAL	8200

⚠1 COULD BE REPLACED BY MODIFIED POWER MODULE

⚠2 IN ADDITION TO COMMUNICATIONS, PLATFORM CAN BE USED FOR METEOROLOGICAL AND ENVIRONMENTAL OBSERVATIONS PAYLOADS
- SEE MULTI-DISCIPLINE PAYLOADS SECTION

GEOSTATIONARY PLATFORM SCENARIO

- Technology development, with its space tests starting in 1984, would not necessarily require Power Module support, since a sortie mission with STS only would suffice. However, the Power Module could provide savings by allowing additional simultaneous missions, either on STS or by continuing to supply platform power after assembly and addition of a variety of platform payloads.

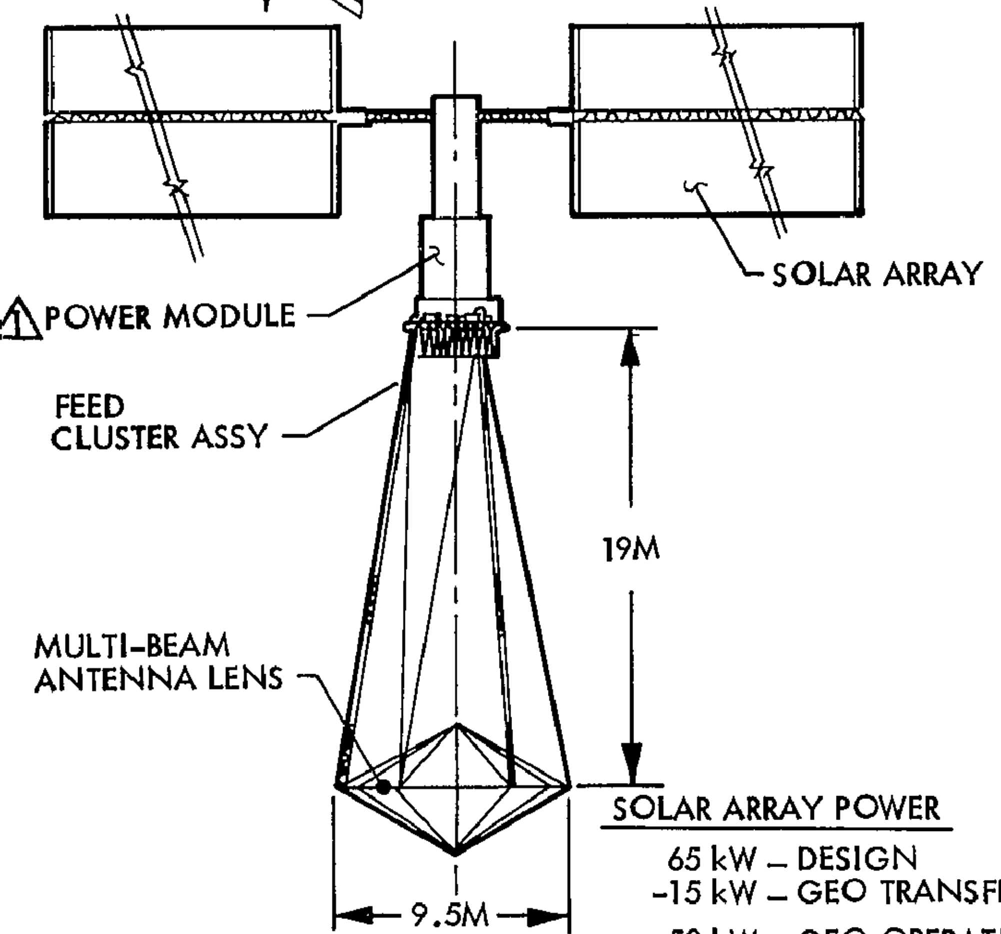
- More clearly definable PM requirements start in 1986 with 25 kW PM support of Step 2 and Step 3 LEO operations. Then, later in Step 3, a GEO Power Module is added for support of final system tests in LEO, ion engine operations in orbit transfer, and long-term GEO operations.

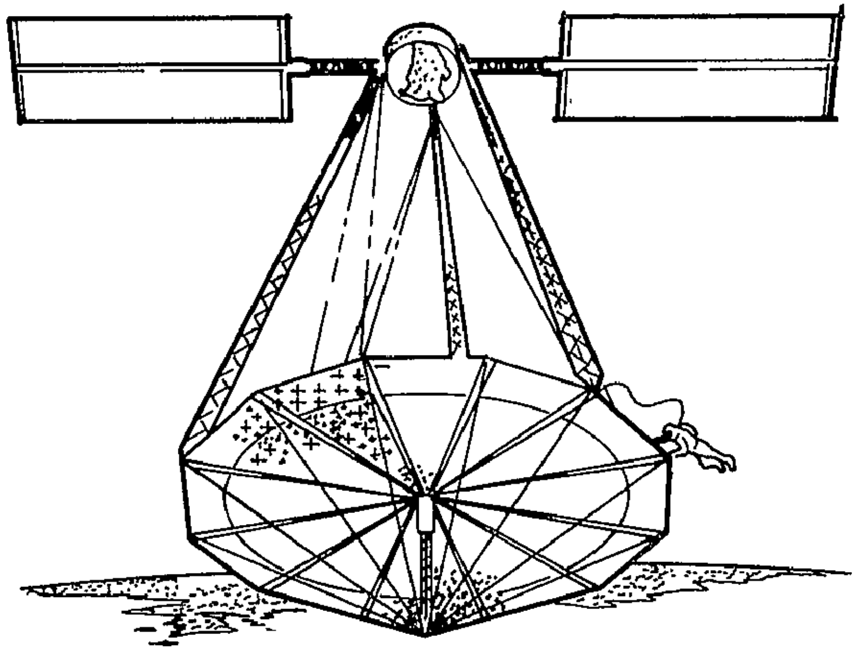
EDUCATIONAL TELEVISION SATELLITE

- In this case, a modified Power Module concept is shown, substituted for the original NASA/Aerospace power, attitude control, and heat rejection systems.

- The 50 kW GEO solar array requirement is well matched to that of the 25 kW PM baseline. Reduced battery, structure, and attitude control weights are projected to result in a 50 kW GEO Power Module weight of perhaps 7,000 kg (specific design work has not yet been done to verify this PM derivation nor the weight).

EDUCATIONAL TELEVISION SATELLITE (1988)





SOLAR ARRAY POWER

65 kW – DESIGN
-15 kW – GEO TRANSFER DEGRADATION
50 kW – GEO OPERATION

WEIGHT (KG)

- COMMUNICATION SYSTEM 3,000

⚠1 COULD UTILIZE SAME SOLAR ARRAY AS LEO 25 kW PM BUT REDUCED BATTERY COMPLEMENT (FOR GEO); CMG'S REPLACED BY SMALLER A/C UNITS.

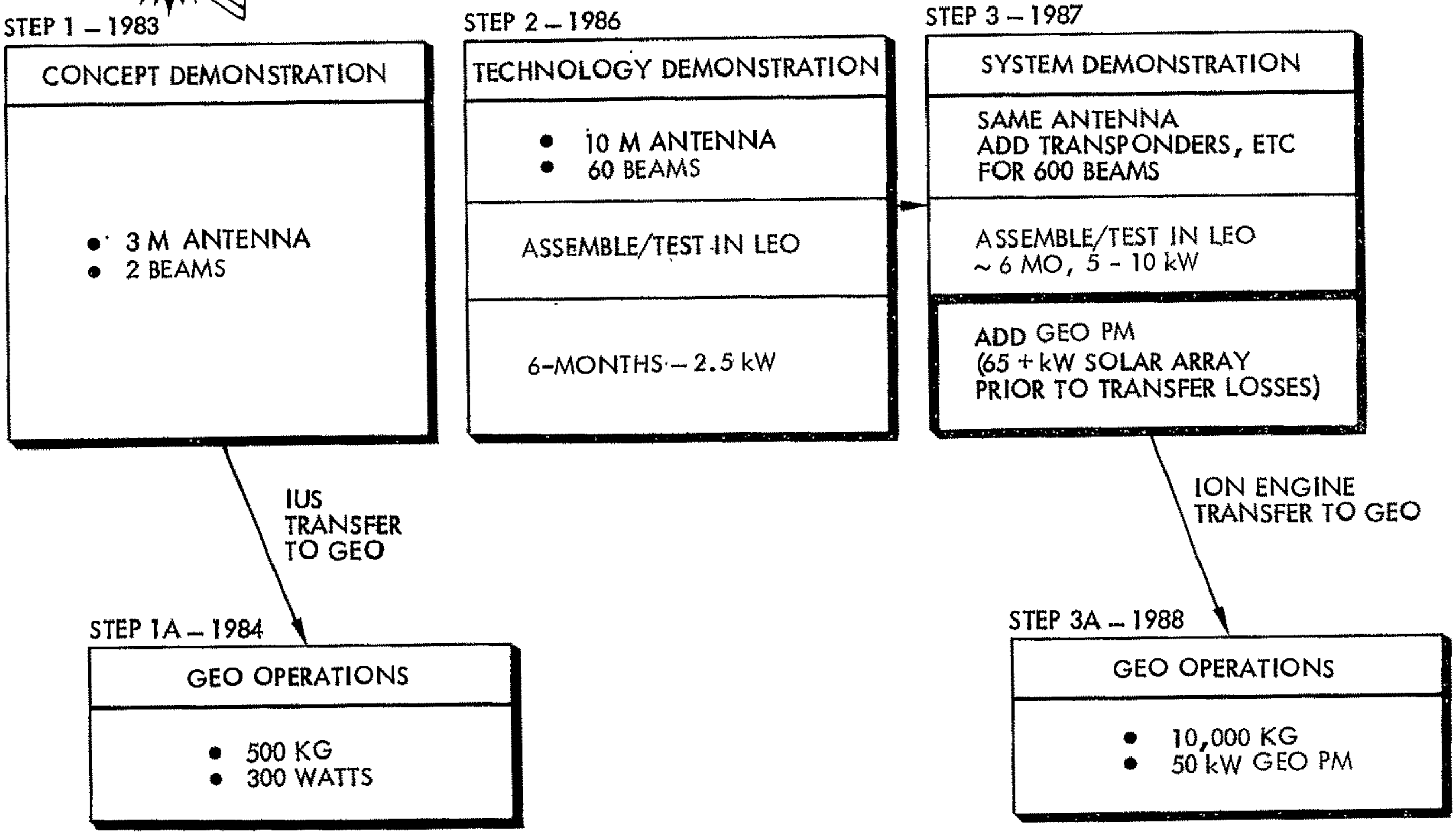
EDUCATIONAL TV SCENARIO

- Step 1, involving only a 3-meter antenna and low power (300 Watts in GEO) does not indicate a need for the Power Module. Step 2 uses the final large antenna and involves 6 months of testing but the power level is also too low to justify dedication of a Power Module to this mission. It may be difficult to combine with other missions, so a special power system for this mission seems indicated. Alternately, the availability of a manned construction platform in 28.5° orbit, serving this and other disciplines, could obviate the need for this special power system.

- Step 3 could be initiated using the special power system designed for Step 2 or construction platform power. Final system testing at higher powers should make use of the GEO Power Module, which establishes the first clean Power Module requirement in this scenario.

- The GEO Power Module would also support ion engine transfer to GEO. Its initial solar cell capability must be at least 65 kW to allow for degradation during ascent and be able to provide 50 kW for long-term GEO operations.

EDUCATIONAL TV SCENARIO



REFERENCE: AEROSPACE "INITIATIVES" STUDY FOR MSFC (MAY 1978)

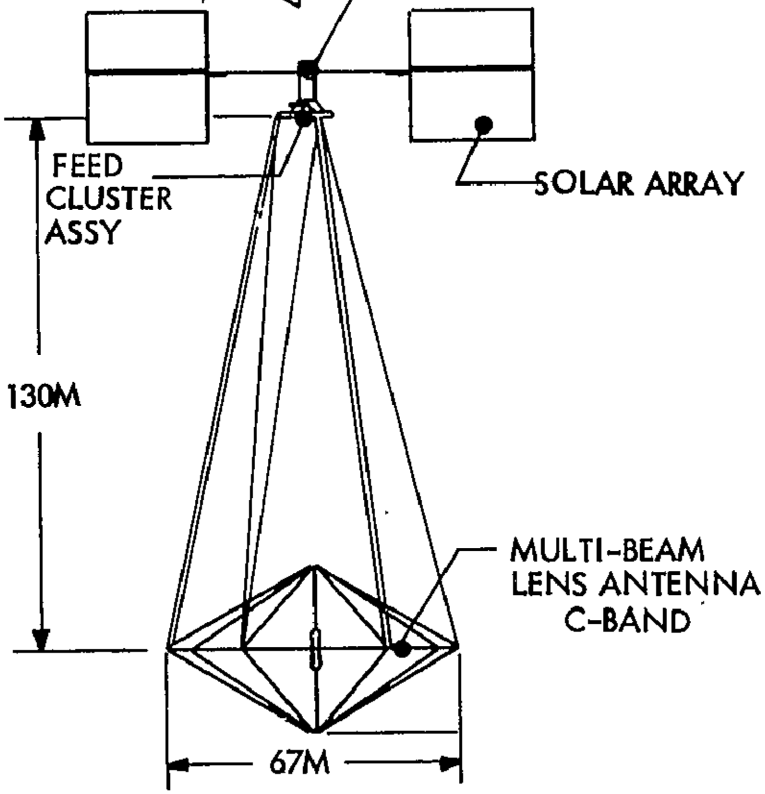
PERSONAL/EMERGENCY COMMUNICATION SATELLITE

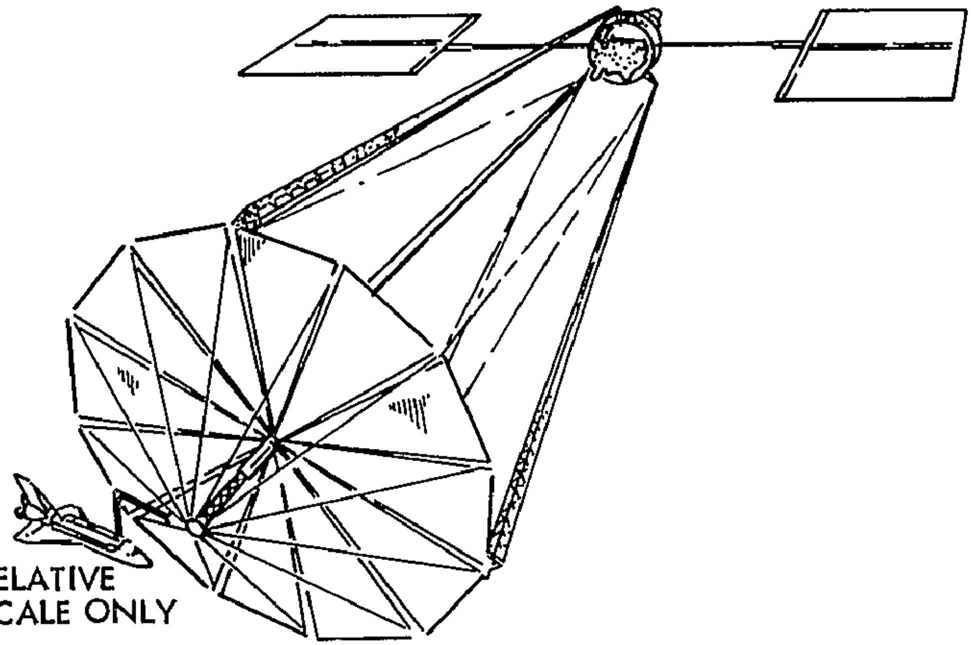
- To provide a 273 kW solar array for this concept will require about four times the array area as used on the 25 kW Power Module and a 16 percent increase is solar array efficiency, which should be available in the late 1980s.

- The battery complement and basic structure of the 25 kW Power Module are comparable to the needs for this GEO application. Attitude control system weights can be reduced by optimizing for GEO operations, probablv employing smaller active control units (wheels, CMGs).

- Power Module weight estimates are not based on design detail at this time; requirements for ejection of payload heat requires further special study.

PERSONAL/EMERGENCY COMMUNICATION SATELLITE (1990)





SOLAR ARRAY POWER

273 kW DESIGN
-63 kW GEO TRANSFER DEGRADATION

210 kW GEO OPERATION

WEIGHT (KG)

• COMMUNICATION SYSTEM	20,000
• POWER MODULE	10,000 ⚠1
TOTAL	30,000

⚠1 ASSUMES BASELINE 25 kW PM STRUCTURE; SIMILAR BATTERY COMPLEMENT; AND 4 TIMES SOLAR ARRAY AREA; CMGs REPLACED BY A/C SMALLER UNITS.

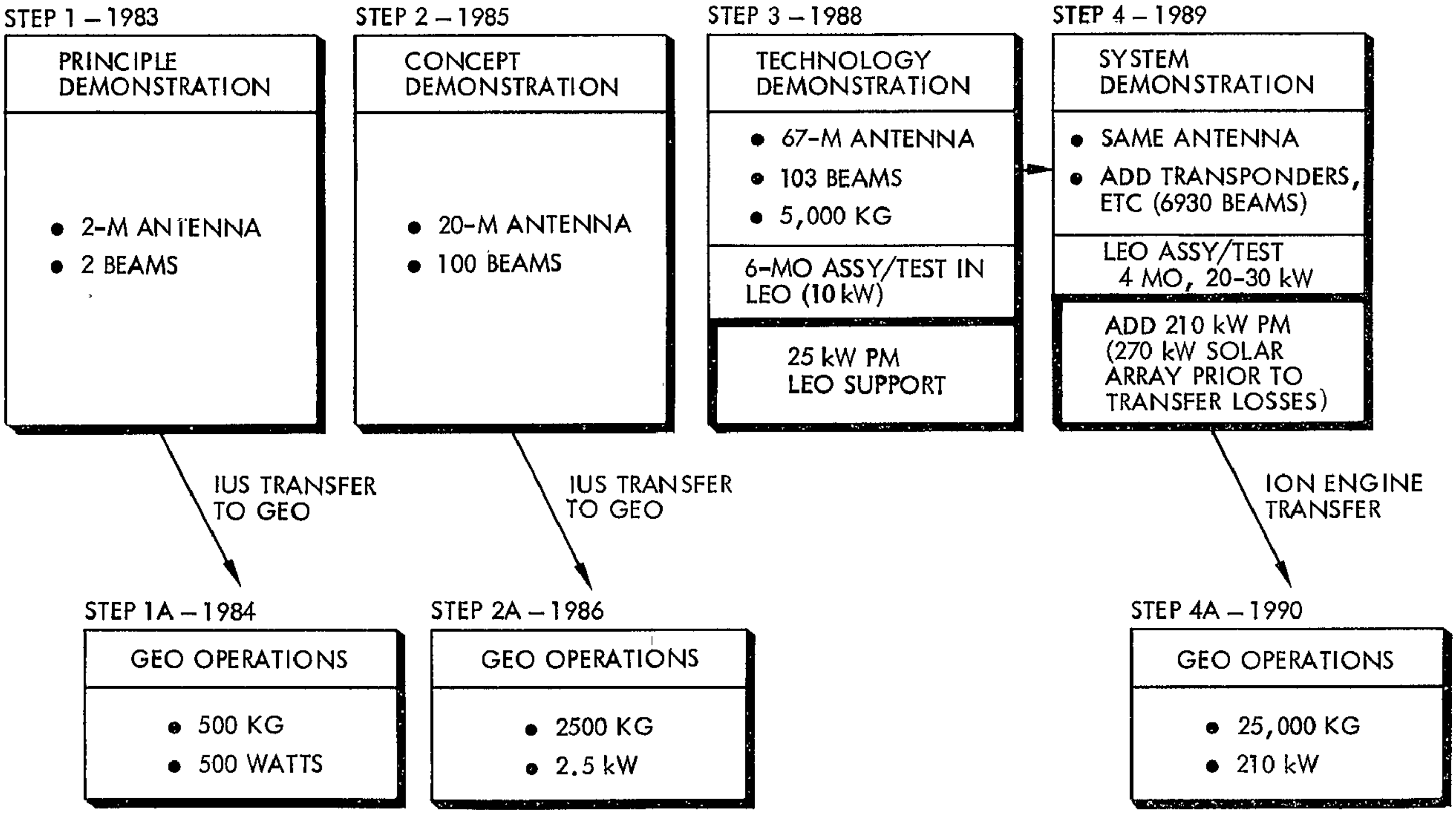
PERSONAL/EMERGENCY COMMUNICATION SCENARIO

- The first clean matching of requirements to Power Module capabilities is at Step 3, projected for 1988. Here the use of a 25 kW Power Module for the planned 6 months of LEO testing should be cost-effective. In fact, if a PM is assigned to this task, the thoroughness of testing would very likely be expanded to make full use of its capability. Alternately, power could be supplied for this assembly and test by a construction platform and power module, if available.

- The Step 4 LEO assembly and test operations in 1989 can also employ a 25 kW PM effectively.

- The GEO Power Module would be added shortly before orbit transfer, used for final system tests in LEO, ion engine transfer to GEO, and finally for long-term GEO operations.

PERSONAL/EMERGENDY COMMUNICATION SCENARIO



REFERENCE: AEROSPACE "INITIATIVES" STUDY FOR MSFC (MAY 1978)

PUBLIC SERVICE PAYLOAD REQUIREMENTS

- LEO assembly and test operations for Public Services systems offer a wide range of Power Module opportunities, possibly as early as 1984 and clearly by 1986. The possibility of a small (30 meter) structure in the 1984 time frame will be further discussed in the Multi-Discipline section, as will the assembly of the 80-meter Geostationary Platform planned for 1986.

- Assembly and Test Power requirements are not generally high and may not make full use of PM capability until 1988 or 1989. Duration requirements exceed STS capabilities soon, however, and the use of PM to support a manned construction base starting as early as 1986 could improve cost-effectiveness by serving a variety of needs. It could readily serve Planetary Spacecraft Assembly, Life Sciences, Energy and possibly Materials Process disciplines as well as Public Services. Some Astronomy payloads could also be added as the base grows. Further discussion of this possibility is also covered in the Multidiscipline Section.

- Pointing requirements, particularly for the large antennas, are quite severe and are drivers for attitude control design of a supporting Power Module.

- Adapting the Power Module for GEO operations is an important consideration in studying its evolution.

PUBLIC SERVICES PAYLOAD REQUIREMENTS

LEO OPERATIONS		SIZE (M)	MASS (KG)	POWER (kW) ⚠2	ORBIT DURATION	HEAT REJECTION (kW)	POINTING ACCURACY (DEG)	PM NEED DATE
GP	STEP 1 – TECHNOLOGY DEV'T	30-M PLAT ⚠1		3-5	30 DAYS	2-3	TBD	1984
	STEP 2 – PLATFORM ASSEMBLY	80-M PLAT	8,000	3-5	30 DAYS	3-5	NA	1986
	STEP 3 – ANTENNA/SYSTEM TEST	30-M, ET AL ANTENNAS	15,000 (TOTAL)	5-10	10-30 DAYS	4-7	0.02 (PLAT:0.5)	1986
EDUCATIONAL TV	STEP 2 ASSY	10-M ANT.	2,000	3-5	5 DAYS	2-3	NA	1986
	STEP 2 TEST			2.5	180 DAYS	2	0.01	1986
	STEP 3 ASSY/TEST			5-10	180 DAYS	3-7	0.01	1987
PERSONAL/EMERGENCY	STEP 3	67-M ANT.	20,000	3-5	60 DAYS	2-3	NA	1988
	STEP 3 TEST			10-20	180 DAYS	7-15	0.01	1988
	STEP 4 ASSY/TEST			20-30	120 DAYS	15-20	0.01	1989
GEO OPERATIONS								
GEO STATIONARY PLATFORM (STEP 3A)		80-M PLAT	15,000	UP TO 40	10+ YR	15 ⚠5	PLAT:0.5; ANTs & SENSORS: 0.02-0.5	1986
EDUCATIONAL TV–(STEP 3A)		10-M ANT.	10,000	50 ⚠3	10-15 YR	40 ⚠5	0.01	1987
PERSONAL/EMERGENCY COMMUN. (STEP 3A)		67-M ANT.	25,000	210 ⚠4	10-15 YR	160 ⚠5	0.01	1989

⚠1 INCLUDES COMMUNICATION AND OTHER ANTENNAS; COULD BE USED AS MULTI-DISCIPLINE PLATFORM WITH PM SUPPORT

⚠2 EXCLUDES POWER FOR MANNED SUPPORT OF LEO ASSEMBLY AND TEST

⚠3 APPROXIMATELY 65 kW SOLAR ARRAY PRIOR TO LEO-GEO TRANSFER

⚠4 APPROXIMATELY 270 kW SOLAR ARRAY PRIOR TO LEO-GEO TRANSFER

⚠5 HEAT REJECTION MAY BE SUPPLIED BY INTEGRAL PAYLOAD SYSTEMS

PUBLIC SERVICE PAYLOADS – CONCLUSIONS

- These conclusions are based on study of a few typical cases out of many alternatives that are being considered for Public Service initiatives. The cases studied appear representative and these conclusions, along with the Specific requirements summarized on the previous chart, form a reasonable basis for the projection of Power Module design evolution. The level of activity is more difficult to predict and quantity of support required has not been estimated; estimates would need to consider the degree of industrial competition which may develop in exploiting the whole range of Public Service opportunities.

- This portion of the study brings out two main points

  - Extensive construction and test operations will be required in a 28.5° LEO orbit in the late 1980s, indicating the desirability of a multidiscipline construction platform as early as 1986.
  - Power requirements for GEO operations can be expected to grow rapidly in the late 1980s, which provides an important area for projection of one branch of Power Module design evolution.

PUBLIC SERVICES PAYLOAD — CONCLUSIONS

OVERALL: PS REQUIREMENTS FOR POWER MODULE START LATE AND GROW RAPIDLY.

1. 25 kW PM COULD BE USED TO SUPPORT EARLY SORTIE MISSIONS (1983, 84, 85) FOR PS EXPERIMENTATION, BUT POWER AND DURATION REQUIREMENTS DO NOT DEMAND ITS USE PRIOR TO 1986.
2. IN 1986, POWER MODULE WILL BE REQUIRED TO SUPPORT LEO ASSEMBLY AND TEST OPERATIONS, PRIMARILY DUE TO DURATION REQUIREMENTS.
   - PM CAN BE SHARED WITH OTHER OPERATIONS
   - 40 TO 60 DAYS ASSY/TEST FOR GEOSTATIONARY PLATFORM
   - 6-MONTH TEST OF EDUCATIONAL TV SYSTEM
3. IN 1988, USE OF A DEDICATED 25 kW PM WILL BE REQUIRED FOR 6-MONTH LEO TEST OF PERSONAL/EMERGENCY COMMUNICATION SYSTEM.
4. MODIFIED POWER MODULES CAN BE USED TO SUPPORT OPERATIONAL PS SYSTEMS IN GEO.
   - 1986 – 50 kW – SOLAR ARRAY COMPARABLE TO 25 kW PM, DECREASE BATTERIES, STRUCTURE, ATTITUDE CONTROL
   - 1988-210 kW – SOLAR ARRAY ABOUT 4X 25kW PM ARRAY; SAME BATTERY WEIGHT AND RACK STRUCTURE, DECREASED ATTITUDE CONTROL SYSTEM WEIGHT

SOLAR/TERRESTRIAL PAYLOADS

- DATA REVIEW
- MISSION OVERVIEW AND SCENARIO
- PROGRAM ELEMENTS
- PAYLOAD HARDWARE
- MISSION CONFIGURATIONS
- HARDWARE CHARACTERISTICS
- PAYLOAD REQUIREMENTS SUMMARY

SOLAR/TERRESTRIAL DATA REVIEW

- Technical data for the Solar Terrestrial payloads have been obtained from many sources. The basic growth scenario, which is defined later in this section; was provided by Messrs. R. Chappell and W. Roberts of MSFC. L. Acton and R. G. Johnson of Lockheed Palo Alto Research Laboratories (PARL) were principal advisors in selection of specific instruments to fit the scenario outline. TRW assisted in providing individual payload data and payload grouping recommendations.

SOLAR/TERRESTRIAL DATA REVIEW

PRIMARY DATA SOURCES

- MSFC SOLAR/TERRESTRIAL OBSERVATORY
- NASA SPACE LAB NO. 1 AND 2 DOCUMENTS
- GSFC (SCIENCE WORKING GROUPS) SOLAR TELESCOPES
- NASA DEFINITION WORKING GROUPS

REFERENCE INFORMATION

AGENCY OR OTHER ORGANIZATION	DISCIPLINE	
MSFC	SOLAR	R. CHAPPELL, W. ROBERTS, M. NEIN, J. BALLANCE
JPL, PASADENA		R. C. WILLSON
GSFC		K. FROST
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UNIV. OF NEW HAMPSHIRE		E. L. CHUPP
STANFORD UNIV.		J. UNDERWOOD
TRW	SOLAR	T. HANES, J. VOGL
MSFC	ATMOS/MAGNETO	R. CHAPPELL, W. ROBERTS
JPL		J. WATERS
NCAR		J. GILLE
TRW		R. FREDERICK, B. TAYLOR, J. VOGL
LOCKHEED PALO ALTO RESEARCH LAB (PARL)	ATMOS/MAGNETO	R. G. JOHNSON

SYSTEM CONSULTATION

- LOCKHEED PARL — L. ACTON, R. G. JOHNSON
- TRW — T. HANES, J. VOGL

SOLAR/TERRESTRIAL MISSION OVERVIEW

- This chart lists and describes the four basic goals of the Solar/Terrestrial (S/T) missions.
- Highlighted as features or objectives are simultaneous observations of solar energy emissions and of their impact on the earth atmosphere and a planned series of space missions where long-duration observations can be made over a period of years, gradually improving the effectiveness of earth environment knowledge and control.
- Throughout this section, the Solar/Terrestrial discipline will be referred to more specifically as the Solar/Terrestrial Observatory or "STO" which, for this report, designates the primary NASA-planned activities in the years 1983 and beyond.

SOLAR/TERRESTRIAL MISSION OVERVIEW

GOALS

SCIENTIFIC INVESTIGATIONS – DEVELOP UNDERSTANDING OF PHYSICAL PROCESSES CONTROLLING THE COMPLEX SUN-EARTH SYSTEM

FORECASTING CAPABILITY – DEVELOP SOLAR/TERRESTRIAL FORECASTING CAPABILITIES FROM ESTABLISHED CAUSE/EFFECT RELATIONSHIPS AND FROM MODELING OF BASIC PHYSICAL PROCESSES

- COMMUNICATIONS EFFECTS
- SPACE ENVIRONMENT (FOR MANNED & UNMANNED USAGE)
- GEOMAGNETIC ACTIVITY
- SHORT-TERM WEATHER EFFECTS
- LONG-TERM CLIMATE EFFECTS

MAN-PRODUCED EFFECTS MONITORING – MONITOR MAN's POLLUTANTS (WAVES, GASES, ETC.) IN AND EFFECTS ON THE UPPER ATMOSPHERE, IONOSPHERE, AND MAGNETOSPHERE

SPACE-ENVIRONMENT MODIFICATIONS – CONDUCT ACTIVE EXPERIMENTS TO EVALUATE THE SENSITIVITY OF THE SPACE ENVIRONMENT TO MAN-MADE PERTURBATIONS (E.G., WAVE INJECTIONS, GASES, PLASMAS, ETC.) AND TO ASSESS THE POTENTIAL FOR MAN's CONTROL OF THE RADIATION BELTS, AURORA, IONOSPHERE, MESOSPHERE, ETC.

FEATURES

FULLY COORDINATED SOLAR/TERRESTRIAL INVESTIGATIONS – PAYLOAD GROUPS REQUIRING HIGH POWER, WEIGHT, VOLUME, ETC., CAN BE OPERATED SIMULTANEOUSLY FOR LONG DURATIONS

MULTIPLE-YEAR, MANY-FLIGHT PROGRAM – PROVIDES THE REQUIRED LONG-DURATION OBSERVATIONS AND OPPORTUNITY FOR EVOLUTION OF SOPHISTICATED MULTI-DISCIPLINE PAYLOADS

STO BASIC SCENARIO

- The current planning of 7 to 14 day Sortie Missions for Spacelab 1 or 2 does not permit an adequate investigation of the solar/terrestrial phenomena required, however, these efforts are very important in STO development. Other STO development Sortie Missions will continue into 1983 and beyond.

- The complete STO Mission Program calls for a three-stage evolvement, considering costs, technology development, availability, and a continuum of long term observation.

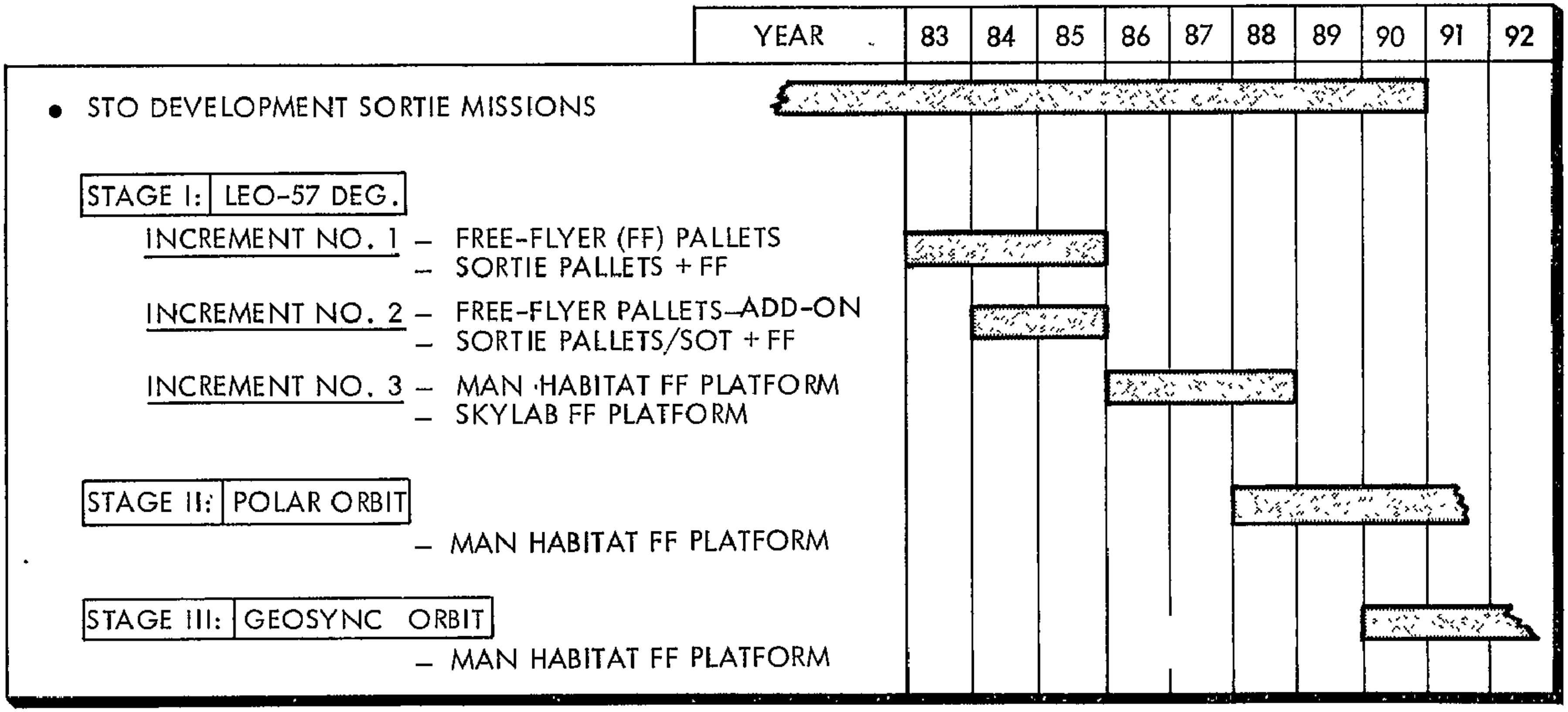
- Stage I in LEO contains three increments. Increment 1 (1983 to 1986) comprises both free-flyers, and Sorties with 30-90 day man interaction. Increment 2 has a similar combination of flights, however, two features make it unique: (1) Free-Flyer — add-ons, and (2) SOT (Solar Optical Telescope).

- Increment 3, starting in 1986 is the first time that trained scientific crews on a rotational basis interact with an STO platform on a long-term basis (1-3 years). STO Development Sortie Missions of 30-90 days are used to test the XUV (Extreme Ultra-Violet) and SXR (Soft X-Ray) large-telescope facilities.

- Stage II beginning in 1988, also comprises a manned habitat/STO platform and provides long-term observation in a polar orbit where the science is different than the preceding flights at 57 deg inclination. It will also require some Sortie flights to develop technology and take advantage of scientific events of opportunity.

- Stage III beginning in 1990, is an early manned habitat STO platform in GEO. It provides viewing of a full earth hemisphere and can observe the large scale coupling between the sun and the earth atmosphere on a continuous or long-term basis. The solar pointing payloads for Stage III are similar to those used for Stage II; the other payloads are conceptualized as advanced versions of LEO types, specially tailored to fit the GEO observation requirements.

STO BASIC SCENARIO



BASIC ELEMENTS OF STO PROGRAM (PLAN)

- This chart illustrates through a matrix the combination of elements comprising the free-flyer, Sortie, and man-habitat missions.

- The three significant features are:

  - A Sortie mission is manned and utilizes a long or short pressurized Spacelab module in conjunction with the cargo bay pallet. In orbit, it is planned on some flights to dock the Orbiter to the PM and free-flying pallet(s), operating the Sortie pallet and free-flyer pallets cooperatively.

  - Whenever the SOT, XUV, or SXR facilities are flown in a Sortie mode, the short pressurized Spacelab module must be used.

  - The SOF (Solar Observatory Facility) consists of SOT, XUV, and SXR in a long spar cluster and allows man's direct supervision and skills to make long term observations.

BASIC ELEMENTS OF STO PROGRAM (PLAN)

STAGE	INCREMENT	TYPE	SOLAR POINTING PACKAGE	SORTIE PALLET(S)	FREE-FLYER (FF) PALLET(S)	DISPLAY CONTROL RACKS	MAN HABITAT	SOLAR FACILITY
STAGE I LEO-57°	INCR 1 ⚠3	SORTIE		X		LSLM		
	(1983-1985)	FREE-FLYER	X		X			
	INCR 2 ⚠3	SORTIE		X		LSLM		
	⚠3	SORTIE (TELESCOPE)				SSLM		SOT
	(1984-1985)	FREE-FLYER	X		X			
	INCR 3 ⚠3	SORTIE (PALLET)		X		LSLM		
	(1986-1989) ⚠3	SORTIE (TELESCOPE)				SSLM		XUV/SXR
		MAN HABITAT FREE-FLYER	X		X	LSLM	⚠1 LSLM (2)	SOF ⚠2
STAGE II POLAR	(1988 ON)	MAN HABITAT FREE-FLYER	X		X	LSLM	LSLM	
STAGE III GEO	(1990 ON)	MAN HABITAT FREE-FLYER	X		X	LSLM	LSLM	–

DEFINITIONS:

- SSLM – SHORT SPACELAB MODULE (PRESSURIZED)
- LSLM – LONG SPACE LAB MODULE (PRESSURIZED)
- SOT – SOLAR OPTICAL TELESCOPE
- ⚠1 – REFURBISHED SKYLAB MAY BE USED AS ALTERNATE

⚠2 – SOLAR OBSERV FACILITY (SOF) CONSISTS OF SOT, XUV & SXR TELESCOPES IN A CLUSTER PLUS A SPECIAL SUPPORT PLATFORM

⚠3 – ALL SORTIES PLANNED FOR COMBINED ORBIT OPERATIONS WITH FREE-FLYER

STO INCREMENT NO. 1 PROGRAM ELEMENTS

- The four basic element groups of Increment 1 are:

  - Solar Pointing Package — which is attached to the power module. It is placed on an EPM, (Experiment Pointing Mount) to continuously montior aspects of the sun.

  - Sortie Pallet(s) — contains payloads which remain in the cargo bay of the Shuttle. More than one pallet may be required. This payload grouping provides the capability for higher quality solar observations and monitoring.

  - LSLM (Long Spacelab Module) Remains in the Orbiter cargo bay and enables trained scientists to: (1) interact with payloads display/control, (2) make scientific correlations and decisions, and (3) take on-site advantage of scientific events of opportunity.

  - Free Flyer Pallet(s) — are attached to the Power Module by the Orbiter RMS. More than one pallet may be required. All payloads in these pallets are directed toward the science of the atmosphere, magnetosphere and plasmas.

- Experiment Pointing Mounts (EPM's) are required on the pallets to assist in viewing the various targets and providing required finer pointing accuracy than is obtainable with the PM or Orbiter.

- The payloads listed under each element and the number designation were used for record-keepin Characteristics of the individual payloads are shown on later charts in this section (entitled "Solar/Terrestrial Hardware Element Characteristics").

STO INCREMENT NO. 1 PROGRAM ELEMENTS

SOLAR POINTING PACKAGE (PM) ⚠1

- SOLAR CONSTANT MONITOR (ST-1)
- SOLAR SPECTRAL IRRADIANCE (ST-2)
- SOFT X-RAY TELESCOPE (ST-3)
- CORONAGRAPH/POLARIMETER (ST-4)
- OPTICAL TLSCPE-MAGNETG'PH (ST-5)
- HARD X-RAY FLARE DET (ST-6)
- EXP'MT POINTING MOUNT (EPM) (ST-37)

LSLM

- DISPLAY/CONTROL

  (UTILIZE EXISTING SPACELAB EQUIPMENT WHERE POSSIBLE)

⚠1 ALL NUMBERS IN PARENTHESES REFER TO LATER INSTRUMENT DESIGNATIONS ON CHARTS

"SOLAR/TERRESTRIAL HARDWARE ELEMENT CHARACTERISTICS."

SORTIE PALLET(S)

- SPEC PURP SOLAR PHYSICS (ST-16)
- XUV SPECTRO HELIOGRAPH (ST-17)
- PLASMA DIAGNOSTIC PACKAGE (ST-18)
- GAS-RELEASE MODULE (ST-19)
- HIGH RESOL TLSCP SPECTROGRAPH (ST-20)
- EPM (2) (ST-37)

FREE-FLYER PALLET(S)

- LOW LIGHT-LEVEL TV (ST-8)
- SEPAC (ST-9)
- X-RAY IMAGER (ST-11)
- LIDAR (ST-12)
- IMAGING SPECTROMETER OBS (ST-14)
- ATMOSPHERIC TRACE MOLECULE (ST-15)
- EPM (ST-37)

STO INCREMENT NO. 2 PROGRAM ELEMENTS

- The four basic element groups mentioned in Increment 1 are identical to those in this Increment except two have been added: Special Sortie Payload and SSLM (Short Spacelab Module).

- The SOT (Solar Optical Telescope) is a large facility telescope. Whenever the SOT is flown in a Sortie mode only the SSLM can be used because of Orbiter space limitations.

- In Increment 2, the Solar Pointing Package payloads referenced in Increment 1 are identical while the payloads of the other elements have undergone some changes (addition, substitution or deletion) due to technology development or observational improvements.

- In both the free flyer pallet(s) and Sortie pallet(s), more than one pallet is required. EPMs are also required to assist payloads in viewing several targets during a single flight period as in Increment 1.

STO INCREMENT NO. 2 PROGRAM ELEMENTS

SOLAR POINTING PACKAGE (PM)

- SOLAR CONSTANT MONITOR (ST-1)
- SOLAR SPECTRAL IRRADIANCE (ST-2)
- SOFT X-RAY TELESCOPE (ST-3)
- CORONAGRAPH/POLARIMETER (ST-4)
- OPTICAL TLSCPE – MAGNETOGRAPH (ST-5)
- HARD X-RAY FLARE DETECTOR (ST-6)
- EPM (ST-37)

FREE-FLYER PALLET(S)

INCREMENT NO. 1 PALLET

- LOW LIGHT LEVEL TV (ST-8)
- SEPAC (ST-9)
- LIDAR (ST-12)
- IMAGING SPECTROMETER OBSERVATORY (ST-14)
- ATMOSPHERIC TRACE MOLECULE (ST-15)
- EPM (ST-37)

INCREMENT NO. 2A PALLET

- CRYO-LIMB INTERFEROMETER RAD (ST-22)
- FABRY-PEROT INTERFEROMETER (ST-23)
- ADVANCED X-RAY IMAGER (ST-11)
- XUV-SOLAR WIND MONITOR (ST-10)
- SOLAR GAMMA RAY SPECTROMETER (ST-7)
- EPM (ST-37)

INCREMENT NO. 2B PALLET

- WAVE INJECTION FACILITY (ST-24)

SORTIE PALLET(S)

INCREMENT NO. 2 PALLET

- SPEC PURPOSE SOLAR PHYSICS CLUSTER (ST-16)
- XUV SPECTRO HELIOGRAPH (ST-17)
- PLASMA DIAGNOSTIC PACKAGE (ST-18)
- ADV GAS/CHEMICAL RELEASE (ST-19)
- MICROWAVE LIMB SCANNER (ST-21)
- EPM (2) (ST-37)

SPECIAL SORTIE PAYLOADS

- SOLAR OPTICAL TELESCOPE (SOT) (ST-28)
- EPM (ST-37)

LSLM

- DISPLAY/CONTROL

SSLM

- DISPLAY/CONTROL

C-2

STO INCREMENT NO. 3 MANNED PLATFORM PROGRAM ELEMENTS

- In Increment No. 3, the Solar Pointing Package and free-flyer pallet elements and payloads are essentially the same as in Increment 2. However, two new elements are added:
  - Solar Observatory Facility — A composite of three large telescopes in a cluster and attached to the Manned Free-Flyer Cluster
  - Man Habitat — A facility for man to live and work in. It will either consist of two long Spacelab modules (modified for free-flyer application) or Skylab and contain life support and display/control capability
- The scientific objectives on the manned platform in this Increment are the same as referred to in Increments 1 and 2. The difference is the man habitat which introduces man for the 1st time to long-term observations and rapid response to solar dynamic events.
- In terms of time phasing, the Solar Observatory Facility operations will occur after Sortie/Test Elements of this Increment are complete; the Sortie/Test elements are shown on the following chart.

STO INCREMENT NO. 3 MANNED PLATFORM ELEMENTS

SOLAR POINTING PACKAGE

- SOLAR CONSTANT MONITOR (ST-1)
- SOLAR SPECTRAL IRRADIANCE (ST-2)
- SOFT X-RAY TELESCOPE (ST-3)
- CORONAGRAPH/POLARIMETER (ST-4)
- OPTICAL TLSCPE – MAGNETOGRAPH (ST-5)
- HARD X-RAY FLARE DETECTOR (ST-6)
- EPM (ST-37)

SOLAR OBSERV FACILITY

- SOT (EPM SOF PLATFORM) (ST-28)
- XUV TELESCOPE (MINUS EPM) (ST-29)
- SXR TELESCOPE (MINUS EPM) (ST-30)

MAN HABITAT

- LSLM (2) OR SKYLAB
- LIFE SUPPORT
- DISPLAY/CONTROL

FREE-FLYER PALLET

INCREMENT NO. 2A PALLET

- CRYO-LIMB INTERFEROMETER RAD (ST-22)
- FABRY-PEROT INTERFEROMETER (ST-23)
- ADVANCED X-RAY IMAGER (ST-11)
- XUV SOLAR WIND MONITOR (ST-10)
- SOLAR GAMMA RAY SPECTROMETER (ST-7)
- EPM (ST-37)

INCREMENT NO. 2B PALLET

- WAVE INJECTION FACILITY (ST-24)

INCREMENT NO. 3A PALLET

- ADV LOW LIGHT-LEVEL TV (ST-8)
- HI POWER ELECTRON ACCEL (ST-25)
- HI POWER ION ACCEL (ST-26)
- HI POWER PLASMA ACCEL (ST-27)
- ADV LIDAR (ST-12)
- EPM (ST-37)

INCREMENT NO. 3B PALLET

- ADV IMAGING SPECTROMETER OBS (ST-14)
- ADV ATMOSPHERIC TRACE MOLECULE (ST-15)
- MICROWAVE LIMB SCANNER (ST-21)
- EPM (ST-37)

STO INCREMENT NO. 3 SORTIE/TEST ELEMENTS

- The Sortie Element of Increment 3 is importantly different in terms of having: (1) on-going capability to respond to dynamic events, and (2) incremental development man-operated payload experiences, resulting ultimately in a manned platform.

- Sortie No. 1 — The payloads for this sortie in conjunction with a LSLM provides the on-going capability (including man, display and control) to respond to dynamic solar events.

- Sortie No. 2 — The SOT payload, complete with SOF support, was a special Sortie payload in Increment No. 2. In Increment No. 3 will be the first part of a three-part facility to be unloaded from the Shuttle and attached to the manned habitat configuration (including man, display, and control) and will have high-quality capability for long-term use.

- Sorties No. 3 and 4 — Each of these sorties is for XUV and SXR large facility telescopes which, after satisfactory test with SSLM and final adjustment will be loaded into the SOF structure on the Manned Habitat cluster, thus completing the SOF.

STO INCREMENT NO. 3 SORTIE/TEST ELEMENTS

SORTIE NO. 1	SORTIE NO. 2	SORTIE NO. 3	SORTIE NO. 4
SORTIE PALLET	SOT (ST-28) ⚠1	XUV TEL FACILITY (ST-29) ⚠2	SXR TEL FACILITY (ST-30) ⚠2
• SPECIAL PURPOSE SOLAR PHYSICS CLUSTER (ST-16)	SOF SUPPORT	• TELESCOPE	• TELESCOPE
• ADVANCED PLASMA DIAGNOSTIC PACKAGE	• EPM	• SUPPORT STRUCTURE	• SUPPORT STRUCTURE
• ADV GAS/CHEM RELEASE	• SOF PLATFORM	• EPM	• EPM
• EPM			
WEIGHT (Kg) 5192	WEIGHT (Kg) 4140	WEIGHT (Kg) 2990	WEIGHT (Kg) 3171
POWER (kW) 0.72 (AVG)	POWER (kW) 2.05 (AVG)	POWER (kW) 2.05 (AVG)	POWER (kW) 2.04 (AVG)
LSLM		SSLM	SSLM
• DISPLAY/CONTROL		• DISPLAY/CONTROL	• DISPLAY/CONTROL

⚠1 PREVIOUSLY TESTED IN INCREMENT NO. 2; LOADED ONTO MANNED PLATFORM IN INCR. NO. 3

⚠2 TESTED AND LOADED ONTO MANNED PLATFORM

STO POLAR PLATFORM ELEMENTS (STAGE II)

- The Man-Habitat configuration is used exclusively in Stage II. No Sortie missions are planned.

- Although the payloads are generally the same or similar, the science in the polar orbit is different and requires some payload alterations/additions. The Solar Pointing Package (SPP) and free-flyer pallets are the same elements developed for Stage I. The payloads are essentially the same but will be refurbished and updated. It was determined for cost reasons that full redevelopment of the payloads would not be desirable. Polar Optics would be one addition (to the free-flyer Pallet No. 1). In the Solar Pointing Package an advanced hard X-ray and gamma ray detector is substituted for the hard X-ray flare detector (of Increments 1, 2, and 3). The XUV Solar Wind Monitor was deleted from Increment 3 pallet and added to the SPP.

- It was determined that payload sizes and varied pointing requirements would not permit the total complement to fit on one pallet or to view different targets simultaneously without one or more Experiment Pointing Mounts (EPM).

STO POLAR PLATFORM ELEMENTS (STAGE II)

FREE-FLYER PALLET(S)

POLAR PALLET NO. 1

- ADV POLAR OPTICS
- ADV LOW LIGHT LEVEL TV
- ADV HI PWR ELECTRON ACCEL
- ADV HI PWR ION ACCEL
- ADV HI PWR PLASMA ACCEL
- ADV LIDAR
- ADV IMAGING SPECTROMETER
- ADV ATMOSPHERIC TRACE MOLECULE
- ADV X-RAY IMAGER
- ADV POLAR MICROWAVE LIMB SCNR
- ADV EPM

POLAR PALLET NO. 2

- ADV CRYO-LIMB INTERFEROMETER
- ADV FABRY-PEROT INTERFEROMETER
- ADV WAVE-INJECTION FACILITY
- ADV POLAR PLASMA DIAGNOSTIC PACKAGE
- ADV EPM

SOLAR POINTING PACKAGE (PM)

- ADV SOLAR CONSTANT MONITOR
- ADV SOLAR SPECTRAL IRRADIANCE
- ADV SOFT X-RAY TELESCOPE
- ADV CORONAGRAPH/POLARIMETER
- ADV OPTICAL TELESCOPE-MAGNETOGRAPH
- ADV HARD X-RAY AND GAMMA-RAY DETECTOR
- ADV XUV SOLAR WIND MONITOR
- ADV EPM

MAN HABITAT (LSLM)

- LIFE SUPPORT
- DISPLAY CONTROL

SUMMARY

	PALLETS NO. 1, NO. 2	SPP	TOTAL
WEIGHT (Kg)	10,000	1,700	11,700
POWER (kW)	–	–	40

STO GEO PLATFORM ELEMENTS (STAGE III)

- Some aspects of Stage III elements are not well known. The payloads of the Solar Pointing Package Element are similar to those of Stage II. Three Instrument groups have been defined. Selection of payloads has been determined to fit the scientific phenomena at GEO. For example: (1) the large scale dynamics of the coupling between the sun magnetosphere, atmosphere and ionosphere can be monitored continuously, (2) one hemisphere of the earth can be observed. These payloads will be mounted on EPM's where appropriate to assist viewing of different targets.

- In this stage, a man habitat is required. A platform structure with other complementary payloads and a central man support is a feasible candidate.

- The power requirements for STO GEO platform (instruments only) is estimated to be 42 kW.

STO GEO PLATFORM ELEMENTS (STAGE III)

INSTRUMENT GROUPS

GEO INSTRUMENT GROUP NO. 1
- ATMOSPHERIC EMISSION IMAGER
- PLASMA SPHERE DYNAMICS PACKAGE
- GLOBAL MICROWAVE LIMB SCANNER
- 3D - OZONE SCANNER
- IR SPECTROMETER PACKAGE
- FORWARD INCOHERENT SCATTER PROBE (FISP)
- EPM

GEO INSTRUMENT GROUP NO. 2
- ADV HI PWR ELECTRON ACCEL
- ADV HI PWR ION ACCEL
- ADV HI PWR PLASMA ACCEL
- ADV GAS/CHEMICAL RELEASE
- LOCAL GEO DIAGNOSTIC PACKAGE
- REMOTE GEO DIAGNOSTIC PACKAGE
- EPM

GEO INSTRUMENT GROUP NO. 3
- WAVE INJECTION FACILITY

SOLAR POINTING PACKAGE
- ADV SOLAR CONSTANT MONITOR
- ADV SOLAR SPECTRAL IRRADIANCE
- ADV SOFT X-RAY TELESCOPE
- ADV CORONAGRAPH/POLARIMETER
- ADV OPTICAL TELESCOPE-MAGNETOGRAPH
- ADV HARD X-RAY AND GAMMA RAY DETECTOR
- ADV XUV SOLAR WIND MONITOR
- ADV EPM

SUMMARY

	INSTRUM. GRPS. 1,2,3	SPP	⚠1 TOTAL
WEIGHT (KG)	16,500	1,700	18,200
POWER (kW)	–	–	42

⚠1 MAN HABITAT NOT SHOWN; TOTAL STO INSTALLATION PROBABLY MOUNTED ON LARGER PLATFORM WITH OTHER PAYLOADS AND CENTRAL MAN SUPPORT

STO SOLAR POINTING PACKAGE (STAGE I, II, AND III)

- The payload equipment for the Solar Pointing Package (SPP) are essentially the same for all three stages except for minor changes.

- The picture shows the instruments located in a cylindrical housing that is mounted on an EPM to provide continuous monitoring of the sun.

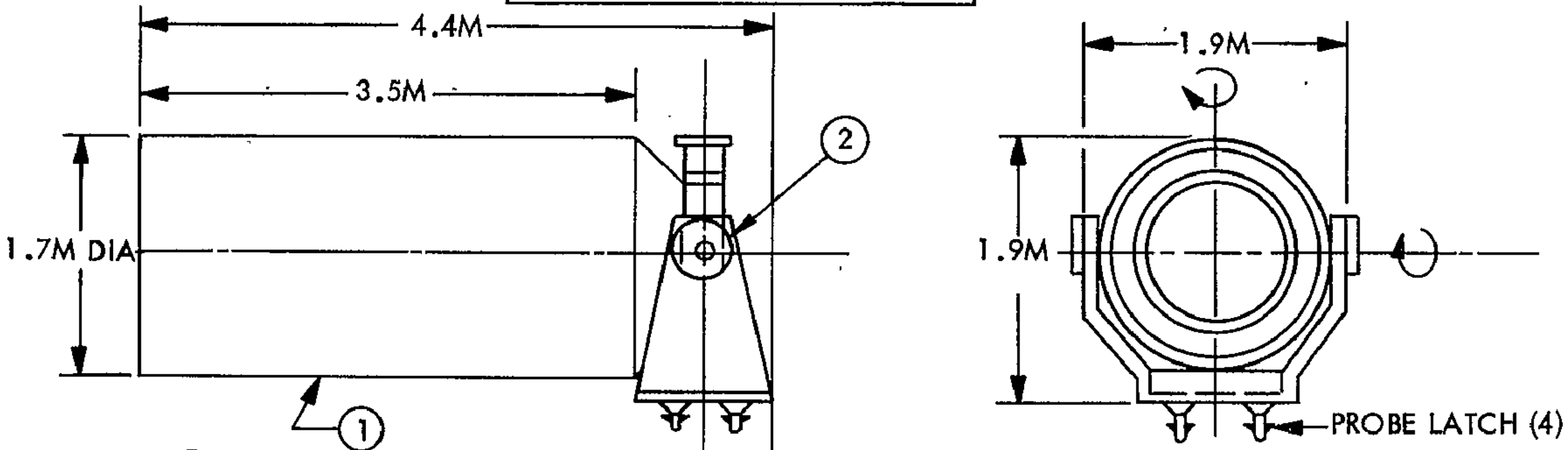
- Basic estimated characteristics are:
  - Stage I – weight 1000 kg; power 0.78 kW
  - Stages II and III – weight 1700 kg; power 1.1 kW

- Probe latches are shown conceptually for mounting of the SPP on the Power Module. It is anticipated that the SPP would continue to operate on orbit during periods when the PM was operating as a free-flyer support vehicle.

STO SOLAR POINTING PACKAGE (STAGE I,II AND III)

POWER REQUIREMENTS (AVERAGE)

STAGE I	0.78 kW
STAGE II, III	1.1 kW △1



(1) PAYLOAD PACKAGE

- INSTRUMENTS

  SOLAR-CONSTANT MONITOR
  SOLAR-SPECTRAL IRRADIANCE
  SOFT X-RAY TELESCOPE
  CORONAGRAPH/POLARIMETER
  OPTICAL TLSCPE – MAGNETOGRAPH
  HARD X-RAY FLARE DETECTOR
- INSTRUMENT SUPPORT ASSY.

(2) • EXPERIMENT POINTING MOUNT (EPM)

	WEIGHT (KG) STAGE I	STAGES II AND III
INSTRUMENTS	800	1400 △1
EPM	200	300
TOTAL	1000	1700 △1

△1 INSTRUMENT-TYPE SUBSTITUTION, ADD-ON PLUS UPDATING, CAUSES INCREASES IN STAGE II AND III POWER REQUIREMENTS AND INSTRUMENT WEIGHT.

STO FREE-FLYER (FF) PALLET EQUIPMENT (INCREMENT NOS. 1 AND 2)

- INCREMENT NO. 1 PALLET

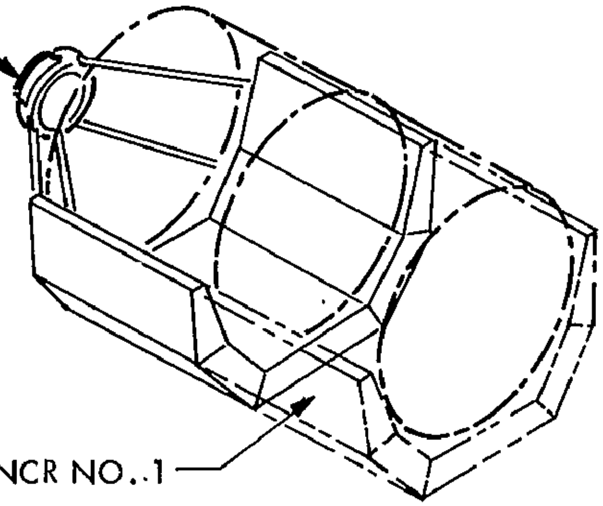
  Although Part I of this study was not devoted to concept design of payloads, it appears that the size of the equipment, location constraints of SEPAC, X-Ray Imager, and LIDAR prevents them from fitting on one pallet.

  Instrument weights and power requirements for the pallets are shown on the chart. These weights do not include the pallet and special instrument support structure weights.

- INCREMENT NOS. 2A AND 2B

  Because of simultaneous viewing requirements, equipment location and size constraints, there are two pallets proposed for Increment 2 free-flyer. The pallets have been designated 2A and 2B for identification later in cluster configuration sketches.

STO FREE-FLYER PALLET EQUIPMENT (INCR NO. 1,2)



POWER REQUIRED (AVERAGE)	
INCR NO. 1	4.6 kW
INCR NO. 2A	0.75 kW
INCR NO. 2B	8.0 kW

INCR NO. 1 PALLET	INCR NO. 2A PALLET	INCR NO. 2B PALLET
• <u>ATMOSPHERE-MAGNETO-SPHERE (AM)</u> – LOW LIGHT-LEVEL TV (ST-8) – SEPAC (ST-9) – X-RAY IMAGER (ST-11) – LIDAR – IMAGING SPECTR'MTR OBS (ST-14) – ATMOS TRACE MOLECULE (ST-15) – EPM (ST-37)	• <u>SOLAR PHYSICS</u> – SOLAR GAMMA RAY SPECT'MTR (ST-7) – XUV SOLAR WIND MONITOR (ST-10) • <u>ATMOSPHERE-MAGNETO-SPHERE (AM)</u> – CRYO-LIMB INTERF RAD (ST-22) – FABRY-PEROT INTERF (ST-23) – ADV X-RAY IMAGER (ST-11) – EPM (ST-37)	• <u>ATMOSPHERE-MAGNETO-SPHERE (AM)</u> – WAVE INJECTION FACILITY (ST-24)
TOTAL WEIGHT (KG) ⚠1 1960	1490	3346

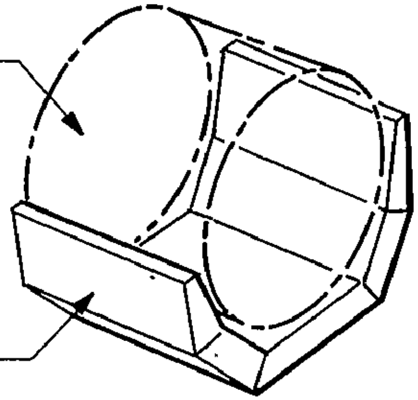
⚠1 INSTRUMENT WEIGHT ONLY; INSTRUMENT SUPPORT STRUCTURE AND PALLET WEIGHT NOT INCLUDED.

STO SORTIE PALLET EQUIPMENT (INCREMENT NOS. 1 AND 2)

- Only one Sortie (Orbiter-mounted) pallet is required for either Increment 1 or 2. The significant increase in weight of Increment 2 pallet over Increment 1 is due to an advanced gas/chemical release system. The total weight of Increment 2 pallet (5539 kg) may require some modification of the baseline pallet structure; this should be investigated in a subsequent study as payload data and specific mounting arrangements are developed.

- Instrument weights and power are shown on the chart for each of the pallets.

STO SORTIE PALLET EQUIPMENT (INCR NO. 1, 2)



POWER REQUIRED (AVERAGE)	
INCR NO. 1	0.97 kW
INCR NO. 2	1.11 kW

INCR NO. 1 PALLET

- SOLAR PHYSICS
  - SPECIAL-PURPOSE PHYSICS CLUSTER (ST-16)
  - XUV SPECTRO-HELIOGRAPH (ST-17)
  - HIGH RESOL TEL SPECTROGRAPH (ST-20)
  - EPM (2) (ST-37)
- ATMOSPHERE-MAGNETOSPHERE (AM)
  - PLASMA DIAGNOSTIC PACKAGE (ST-18)
  - GAS/CHEM RELEASE (ST-19)

TOTAL WEIGHT (KG) ⚠1 1244

INCR NO. 2 PALLET

- SOLAR PHYSICS
  - SPECIAL PURPOSE PHYSICS CLUSTER (ST-16)
  - XUV SPECTRO-HELIOGRAPH (ST-17)
  - EPM (ST-37)
- ATMOSPHERE-MAGNETOSPHERE (AM)
  - PLASMA DIAGNOSTIC PACKAGE (ST-18)
  - ADV GAS/CHEM RELEASE (ST-19)
  - MICROWAVE LIMB SCANNER (ST-21)

TOTAL WEIGHT (KG) ⚠1 5539

⚠1 WEIGHTS FOR INSTRUMENTS ONLY; INSTRUMENT SUPPORT STRUCTURE AND PALLET WEIGHT NOT INCLUDED

STO SOLAR OBSERVATORY FACILITY (SOF)

- The SOF is a man-operated solar-observation telescope facility comprising a single structural mounting which will support three separate telescopes to be installed and tested one at a time on separate orbiter sortie flights. (See page ID-17). The final SOF is installed on an orbiting manned platform (shown on page ID-38).

- The Long Spar cluster of three telescopes has been planned by NASA as recently as 1978 for sortie flights on the Orbiter in the late 1980's. The conversion of the SOF to a manned-platform mounting for Increment 3 of the STO program is part of the proposed payload approach in this report.

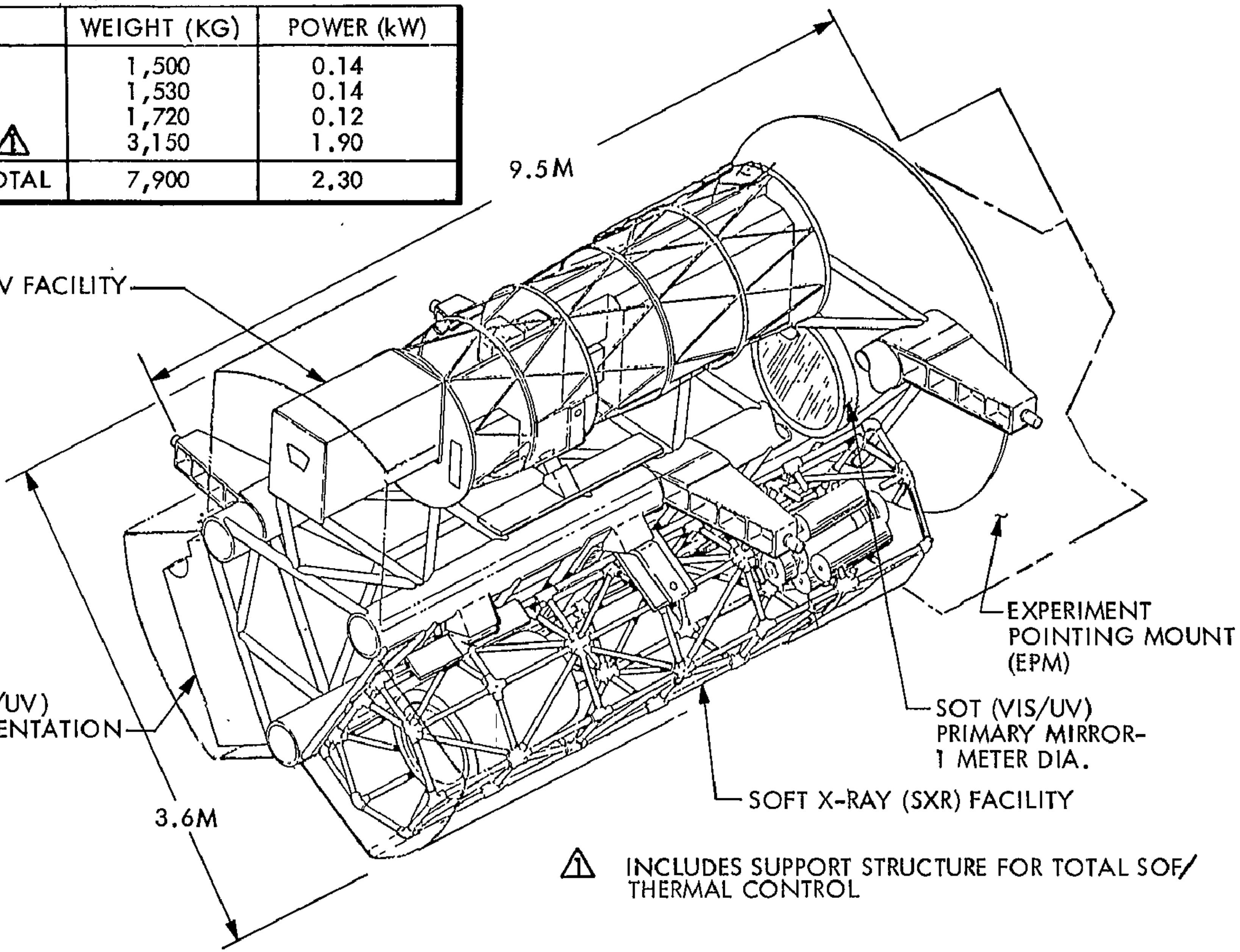
- Weights for cluster support structure and EPM support have been included in the weight tables shown. Power for the total system is also shown on the chart. Weight and power numbers are for the instrument only and do not include the control/display for man interaction. ⚠1

- The incremental buildup of the SOF in Increment 3, following Sortie/test flights, has been discussed on previous charts.

⚠1 The required control/display will be included in the man-habitat and workshop on the manned platform or in the Spacelab Module on the sortie flights.

STO SOLAR OBSERVATORY FACILITY (SOF)

ITEM	WEIGHT (KG)	POWER (kW)
SOT	1,500	0.14
XUV	1,530	0.14
SXR	1,720	0.12
EPM ⚠1	3,150	1.90
TOTAL	7,900	2.30



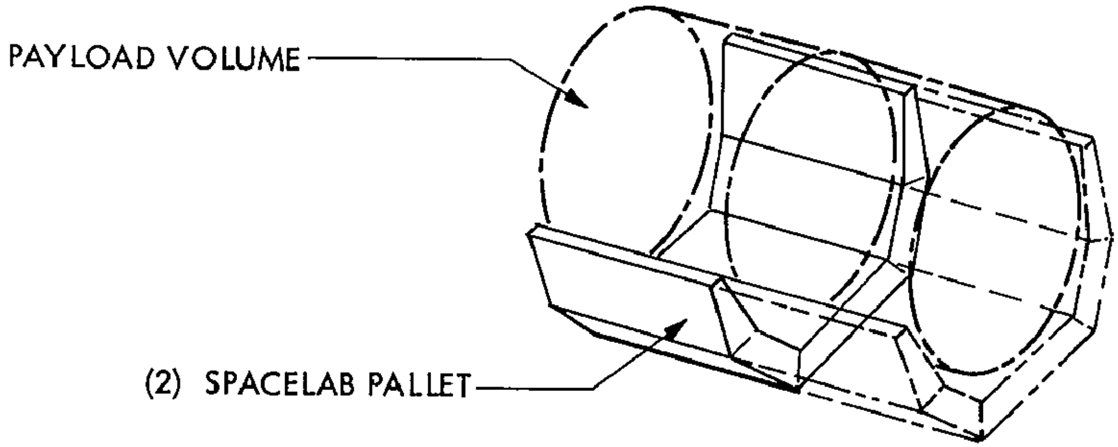
⚠1 INCLUDES SUPPORT STRUCTURE FOR TOTAL SOF/ THERMAL CONTROL

STO FREE-FLYER PALLET EQUIPMENT (INCREMENT NO. 3)

- To improve the scientific investigation in 1986, the technology is assumed to improve. This is reflected in the power and weight increases of Pallet 3A over use of similar payload equipment on free-flyer pallet Increment 1.

- This set of payloads can be considered a replacement for the Increment 1 free-flyer.

STO FREE-FLYER PALLET EQUIPMENT (INCR NO. 3)



POWER REQUIRED (AVERAGE)	
INCR NO. 3A	9.6 kW
INCR NO. 3B	1.3 kW

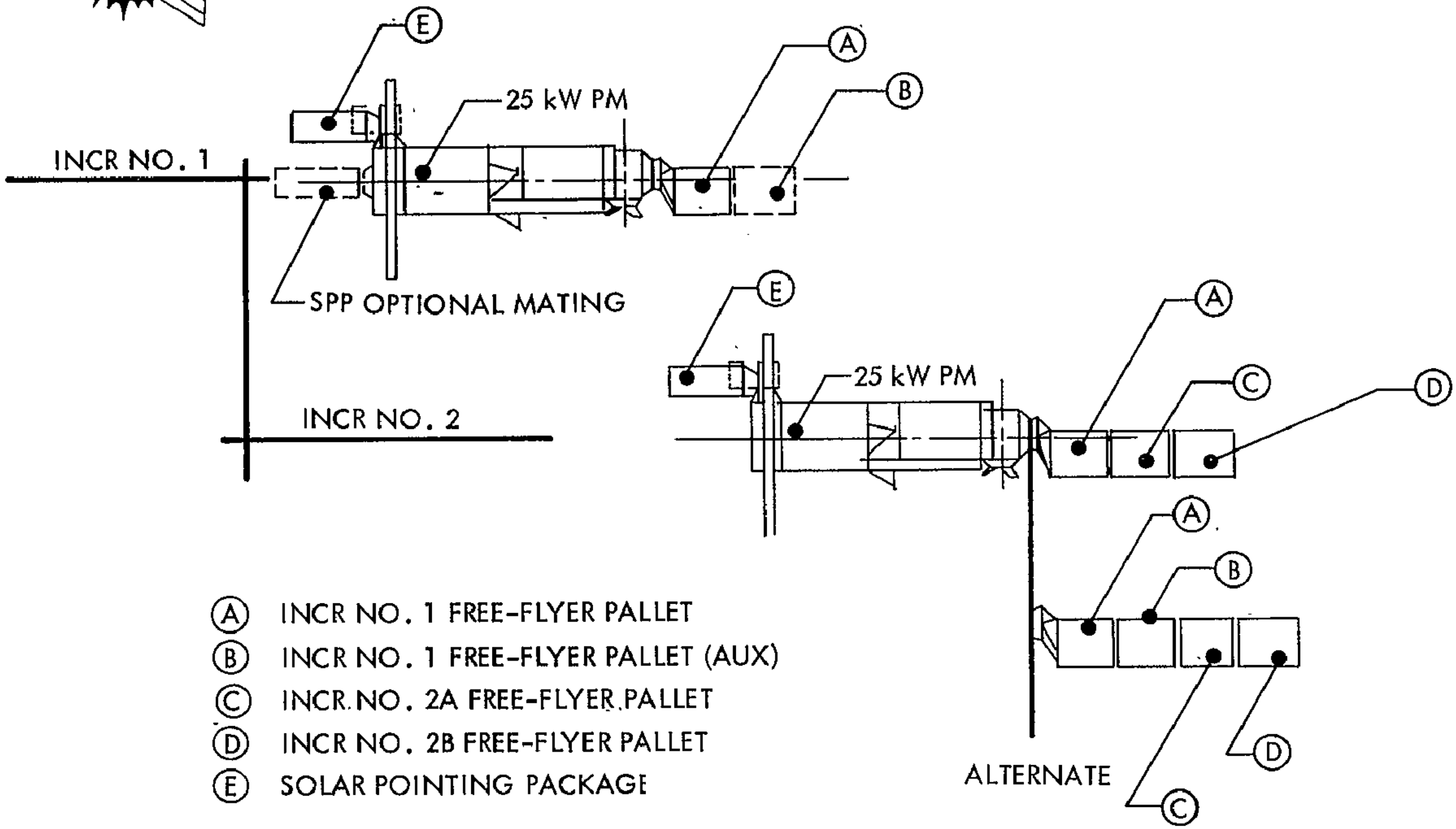
INCR NO. 3A PALLET	INCR NO. 3B PALLET
• ATMOSPHERE-MAGNETOSPHERE (AM) – ADV. LOW LIGHT LEVEL TV (ST-8) – HI-PWR ELECTRON ACCEL (ST-25) – HI-PWR ION ACCEL (ST-26) – HI-PWR PLASMA ACCEL (ST-27) – ADV LIDAR (ST-12) – EPM (ST-37)	• ATMOSPHERE-MAGNETOSPHERE (AM) – ADV IMAGING SPECTR'MTR (ST-14) – ADV ATMOS TRACE MOLECULE (ST-15) – MICROWAVE LIMB SCANNER (ST-21) – EPM (ST-37)
TOTAL WEIGHT (KG) ⚠1 2184	1209

⚠1 INSTRUMENT WEIGHT ONLY; INSTRUMENT SUPPORT STRUCTURE AND PALLET WEIGHT NOT INCLUDED

STO FREE-FLYER/PM PALLET ARRANGEMENT

- This chart shows typical arrangements of one or more STO pallets supported in a free-flying mode by the PM.
- The concept requires a solar pointing package on the power module (to point continuously at the sun) and track with the solar arrays. The pallets are attached to the aft docking port on the PM.
- Rotational orientation of pallets to the PM (for viewing of targets) and the development of simplified latch/delatch mechanisms for addtion/removal on orbit of pallets in a train should be determined in later studies as payload groupings are defined more specifically.

STO FREE-FLYER/PM PALLET ARRANGEMENT



(A) INCR NO. 1 FREE-FLYER PALLET
(B) INCR NO. 1 FREE-FLYER PALLET (AUX)
(C) INCR.NO. 2A FREE-FLYER PALLET
(D) INCR NO. 2B FREE-FLYER PALLET
(E) SOLAR POINTING PACKAGE

STO SORTIE/SHUTTLE-TENDED ARRANGEMENT INCREMENT NO. 1

- This arrangement illustrates a typical Orbiter STO Sortie complement docking with the free-flyer (FF). The Orbiter will have display/control capability inside the LSLM (Long Spacelab Module) permitting man to interact with payloads in three elements.

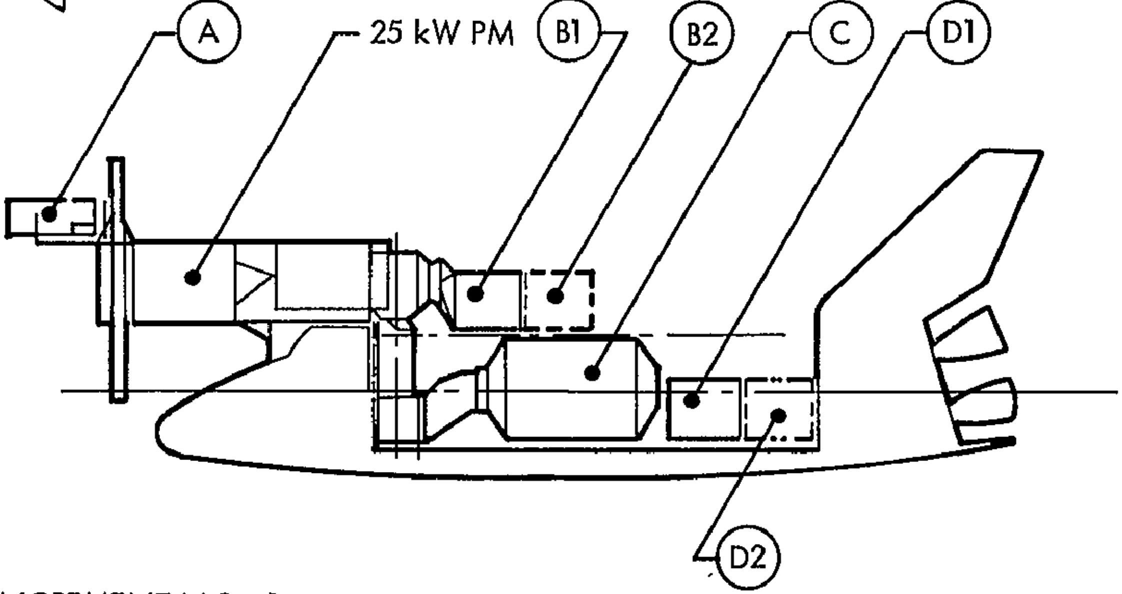
  - Solar Pointing Package

  - FF Pallets

  - Sortie Pallets

- This flight mode will also be used for checkout of free-flyer payloads and addition or exchange of free-flyer pallets.

STO SORTIE/SHUTTLE-TENDED ARRANGEMENT – INCR NO. 1



INCREMENT NO. 1

- (A) SOLAR POINTING PACKAGE
- (B1) FREE-FLYER INCREMENT NO. 1 PALLET
- (B2) AUXILIARY INCREMENT NO. 1 FREE-FLYER PALLET
- (C) DISPLAY/CONTROL RACKS (LSLM)
- (D1) SORTIE INCREMENT NO. 1 PALLET
- (D2) AUXILIARY INCREMENT NO. 1 PALLET

STO SORTIE/SHUTTLE – TENDED ARRANGEMENT (INCREMENT NO. 2)

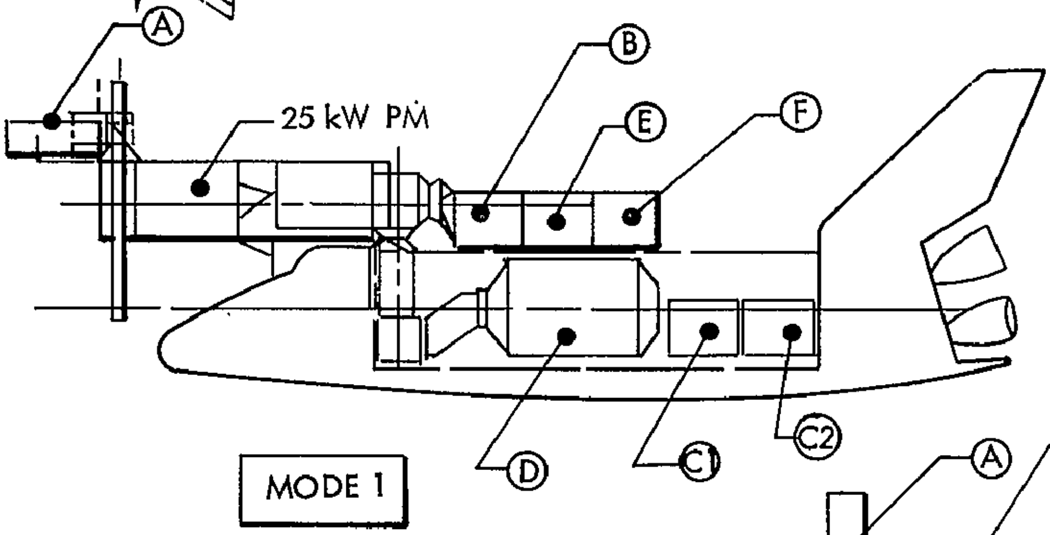
- There are two Sortie modes in this increment.

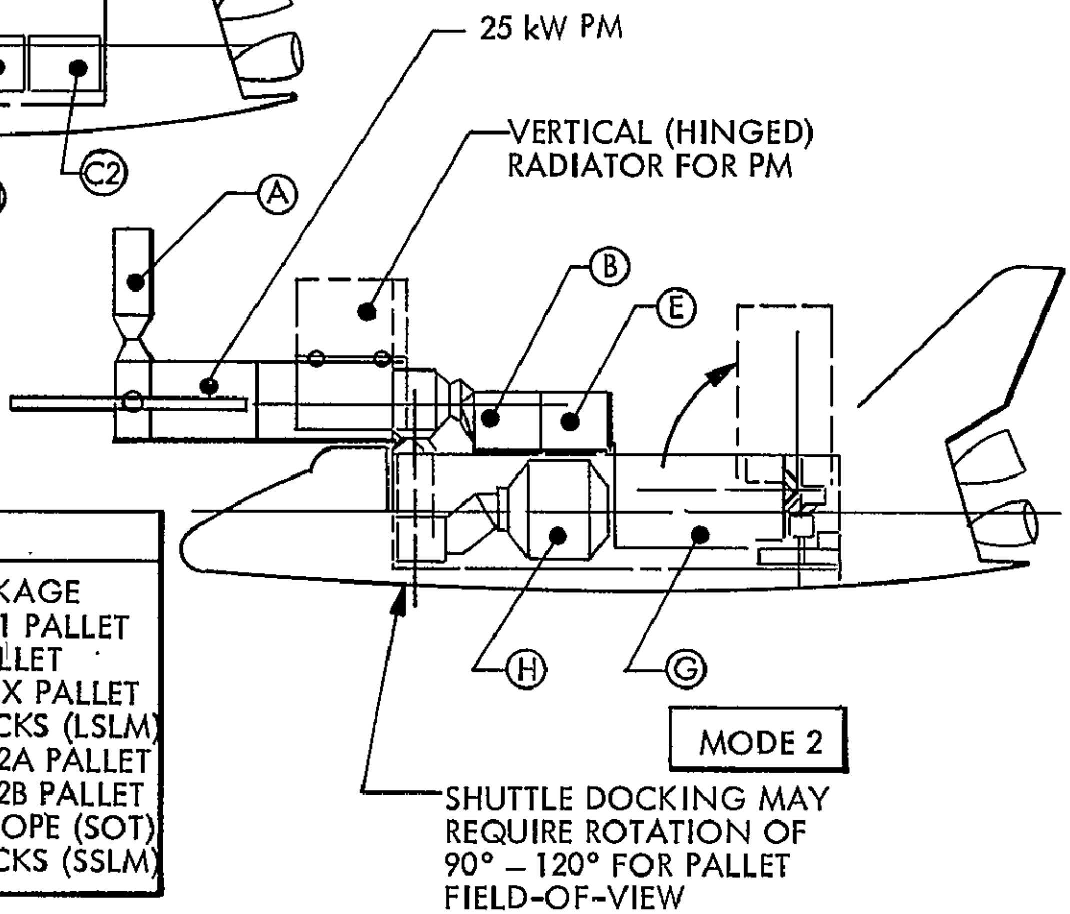
  Mode 1 – shows the free-flyer with three attached pallets and docked with the Orbiter. The Orbiter carries a LSLM and two Sortie pallets (one is auxiliary).

  Mode 2 shows the free-flyer with two attached pallets and docked with the Orbiter. The Orbiter carries a SSLM and the SOT (Large Telescope).

- The use of SOT in Mode 2 creates a potential mechanical blockage if more than two free-flyer pallets are mounted on the PM. Solar pointing of the extended SOT may also cause heat rejection difficulties and force the PM (and possibly the payload pallets) to use hinged radiators for larger heat rejection. Rotation of the Orbiter about its docking axis may aid the mechanical interference, however, the heat rejection problem should be resolved in a later study. Within the scope of the Part I study, these interface conditions could not be worked down to an adequate hardware solution. An attempt has been made to point out principal payload and general interface characteristics which may influence the PM system.

STO SORTIE/SHUTTLE-TENDED ARRANGEMENT





MODE 1	MODE 2	STO ELEMENT	
X	X	A	SOLAR POINTING PACKAGE
X	X	B	FREE-FLYER INCR NO. 1 PALLET
X		C1	SORTIE INCR NO. 2 PALLET
X		C2	SORTIE INCR NO. 2 AUX PALLET
X		D	DISPLAY/CONTROL RACKS (LSLM)
X	X	E	FREE-FLYER INCR NO. 2A PALLET
X		F	FREE-FLYER INCR NO. 2B PALLET
	X	G	SOLAR OPTICAL TELESCOPE (SOT)
	X	H	DISPLAY/CONTROL RACKS (SSLM)

STO SORTIE/SHUTTLE-TENDED ARRANGEMENT (INCREMENT NO. 3)

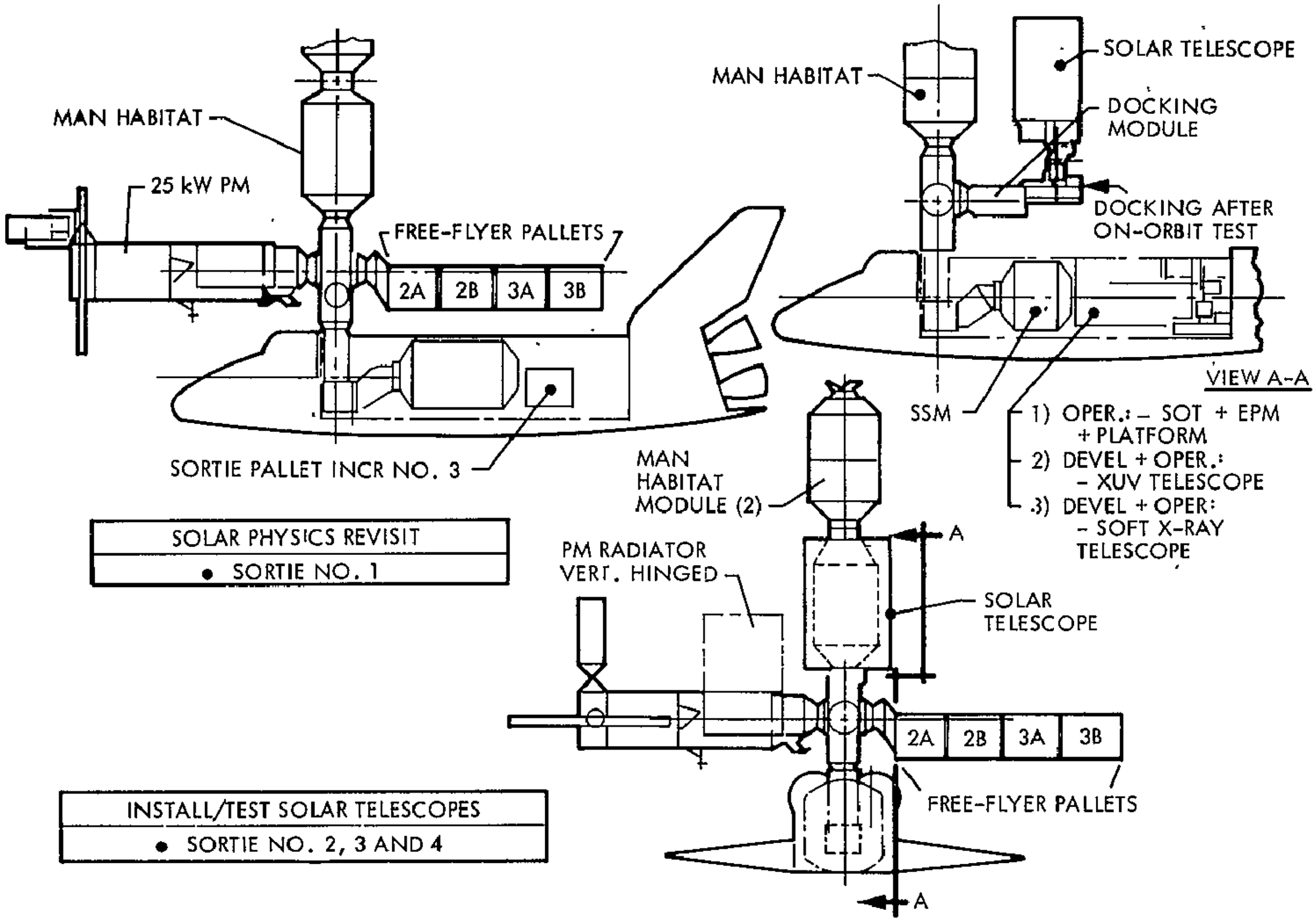
- In this chart, configurations are shown separately for Sortie No. 1 and combined Sorties No. 2, 3, and 4.

- Sortie No. 1 is almost identical to other configurations of the Orbiter carrying a LSLM, a Sortie pallet and docked to the power module. To obtain view clearance for the Sortie pallet, the Orbiter would probably require rotation about the docking centerline (as shown in the lower center illustration).

- Sorties No. 2, 3, and 4 configurations are similar. In Sortie 2, the SOT is not operated while in the Orbiter, but rather unloaded and attached to a docking module with integral SOF platform and EPM. Sorties 3 and 4 carry the XUV and SXR telescopes respectively. These telescopes are operated while in the Orbiter. Upon successful completion of test and adjustments, telescopes are unloaded and inserted into the SOF structure to complete the cluster of three telescopes.

- Combinations of viewing requirements of the solar-pointing payloads and the heat rejection from the PM radiators may again require consideration of hinged PM radiators and/or payload pallet radiators. The orientations shown are intended principally to identify hardware elements of the system and not preferred cluster configurations or Orbiter docking orientation.

STO SORTIE/SHUTTLE-TENDED ARRANGEMENT — INCR NO. 3



SOLAR PHYSICS REVISIT
• SORTIE NO. 1

INSTALL/TEST SOLAR TELESCOPES
• SORTIE NO. 2, 3 AND 4

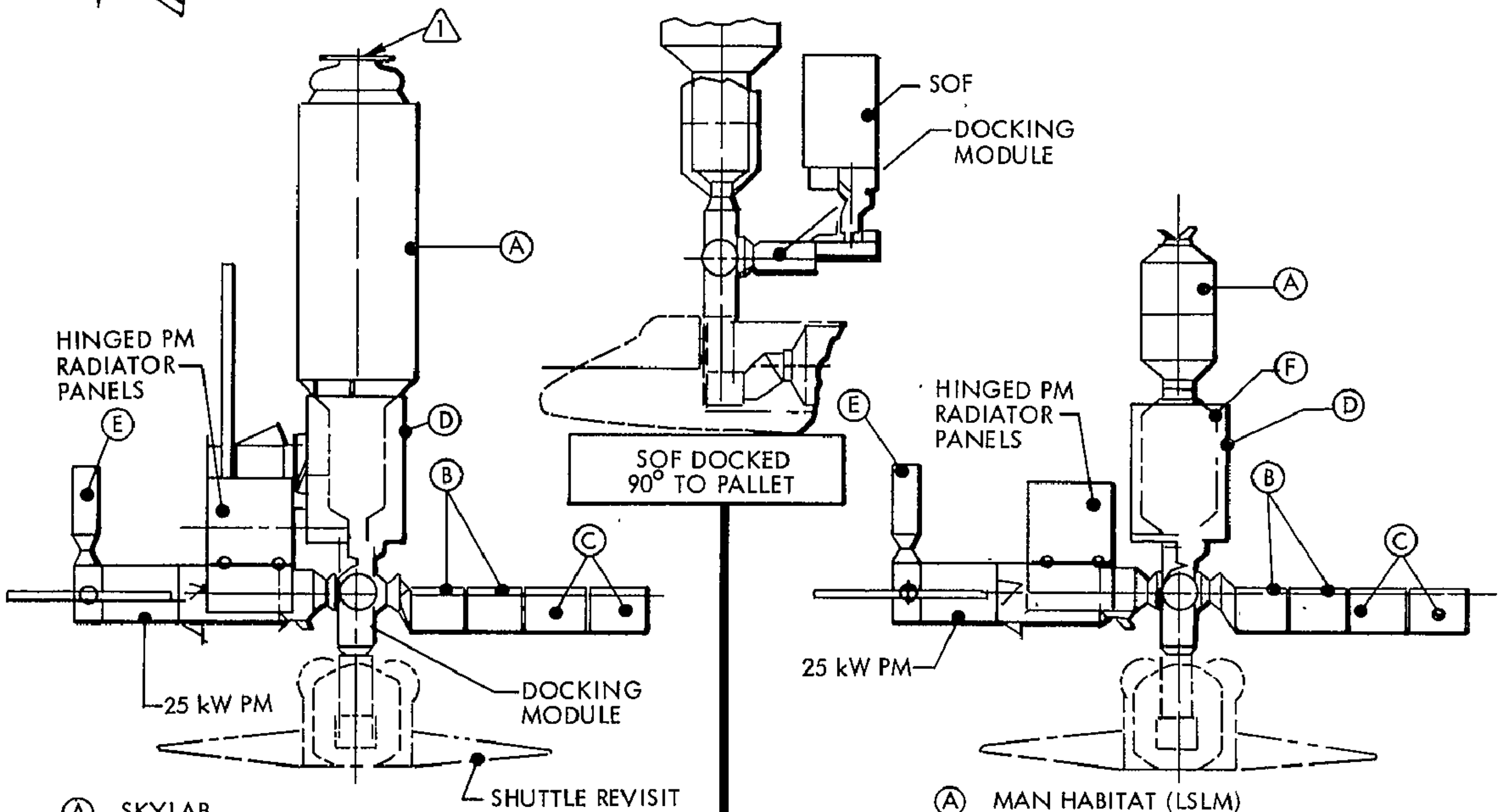
STO MANNED PLATFORM INCREMENT NO. 3

- This chart shows two typical manned STO platforms; one using Skylab and one using a double-LSLM as a man-habitat and a display control center. These configurations are essentially the same as described in the previous chart.

- An important difference is that the Orbiter is essentially constrained to revisits only (personnel rotation and maintenance) and no display control module is planned for use on the Orbiter (Sortie missions having been completed).

- The problem of viewing from the pallets may be simplified but the heat rejection implementation combined with the solar-pointing of the SOF may continue to evolve special arrangements on such a cluster platform or at least use of additional or alternate heat-rejection radiators

STO MANNED PLATFORM – INCR NO. 3



Ⓐ SKYLAB
Ⓑ FREE-FLYER INCR NO. 2A AND 2B PALLETS
Ⓒ FREE-FLYER INCR NO. 3A AND 3B PALLETS
Ⓓ SOLAR OBSERVATORY FACILITY
Ⓔ SOLAR POINTING PACKAGE
⚠1 NOTE: ORIENTATION OF HARDWARE ELEMENTS SKYLAB, ETC; WILL BE STUDIED IN PARTS II, III OF STUDY (E.G., RADIATORS)

Ⓐ MAN HABITAT (LSLM)
Ⓑ FREE-FLYER INCR NO. 1 PALLET
Ⓒ FREE-FLYER INCR NO. 2A PALLET
Ⓓ SOLAR OBSERVATORY FACILITY
Ⓔ SOLAR POINTING PACKAGE
Ⓕ DISPLAY/CONTROL RACKS (LSLM)

SOLAR/TERRESTRIAL HARDWARE ELEMENT CHARACTERISTICS

- The next four pages present a summary listing of all STO hardware and their pertinent characteristics developed during the Part I study. It includes a combination of currently-planned instruments as well as projected future technology units which are intended to enhance the solar/terrestrial scientific knowledge.

- ST-1, etc., are the payload designators assigned for record keep and will correlate with those elsewhere in this section.

- ST-10 and ST-13 are not shown within the bracket of the Solar Pointing Package because initially ST-10 was used in a pallet, then later in Stage II pointing package. ST-13 is a combination of ST-6 and -7. Prior to combining, ST-7 was used in a pallet.

- Any data ranges shown in the power, weight, or volume columns indicates variation from initial to growth version.

SOLAR/TERRESTRIAL HARDWARE ELEMENT CHARACTERISTICS

		PAYLOADS	PWR (1) (kW)	WT (1) (KG)	VOL. (1) (M^3)	POINTING (3)	TARGET
SOLAR POINTING PACKAGE	ST-1	SOLAR CONSTANT MONITOR	0.01	11	0.01	2°	SUN
	-2	SOLAR SPECTRAL IRRADIANCE MEAS'MT	0.08	10	0.01	±30 $\widehat{S}$	SUN
	-3	SOFT X-RAY (SXR) TELESCOPE	0.03	160	1.0	10 $\widehat{S}$	SUN
	-4	CORONAGRAPH/POLARIMETER	0.05	110	0.80	10 $\widehat{S}$	SUN
	-5	OPTICAL TELESCOPE MAGNETOGRAPH	0.40	320	0.44	(5) 0.01 $\widehat{S}$	SUN
	-6	HARD X-RAY FLARE DETECTOR	0.01	40	0.08	6°	SUN
	-7	SOLAR GAMMA RAY SPECTROMETER	0.01	120	0.22	1°	SUN
	-8	LOW LIGHT-LEVEL TV	0.41	230	0.17	0.1 $\widehat{M}$	VARIOUS
	-9	SEPAC (SPACE EXPER. + PARTICLE ACCEL.)	0.75	360	0.80	2°	ALONG MAGNETIC FIELD
	-10	XUV SOLAR WIND MONITOR	0.05	110	0.82	±10 $\widehat{S}$	SUN

NOTES:

(1) DATA SHOWN INDICATES RANGE FROM INITIAL TO GROWTH VERSION

(2) DOES NOT INCLUDE 25 M DIA GEO ANTENNA

(3) INTEGRAL GIMBAL PLATFORM PROVIDED FOR ALL PAYLOADS WITH POINTING LESS THAN 30 ARC SEC

(4) EPM SIMILAR TO IPS OR SIPS

(5) BUILT-IN SECONARY TRACKER FOR POINTING

(6) DOES NOT INCLUDE 30-100 M DIA GEO ANTENNA

SOLAR/TERRESTRIAL HARDWARE ELEMENT CHARACTERISTICS (CONT)

	PAYLOADS	PWR (1) (kW)	WT (1) (KG)	VOL, (1) (M^3)	POINTING (3)	TARGET
ST-11	X-RAY IMAGER	0.30	120	0.87	N/A	VARIOUS
-12	LIDAR (LASER SOUNDER)	3.0-7.0	780-1430	6.8-8.2	2°	NADIR
-13	HARD X-RAY AND GAMMA RAY DETECTOR	0.01	120	0.22	1°	SUN
-14	IMAGING SPECTROMETER OBSERVATORY	0.10	410	1.2	0.5°	BASICALLY DOWN
-15	ATMOSPHERIC TRACE MOLECULE	0.36	360	0.44	±4°	EARTH LIMB
-16	SPECIAL PURPOSE SOLAR PHYSICS CLUSTER:	0.24	320	3.6	±1 S	SUN
	– DUAL WHITELIGHT CORONAGRAPH				±20 S	SUN
	– UV SCANNING POLY SPECTRO-HELIOGRAPH				±25 S	SUN
	– X-RAY SPECTROM-SPECTROGR TELESCOPE				±1 S	SUN
	– H-ALPHA 1 TELESCOPE				±1 S	SUN
-17	XUV SPECTROMETER – HELIOGRAPH	0.03	170	0.7	1 M	SUN
-18	PLASMA DIAGNOSTIC PACKAGE	0.10	290	3.0	N/A	ALONG MAGNETIC FIELD
-19	GAS/CHEMICAL RELEASE	0.12	50-8310	0.3-9.6	N/A	
-20	HIGH RESOLUTION TELESCOPE SPECTROGRAPH	0.10	160	0.57	20 S	SUN
-21	MICROWAVE LIMB SCANNER	0.5-3.0	275-350 (2)	1.0-1.5 (2)	3°-$10^{-6^{\circ}}$	LIMB

SOLAR/TERRESTRIAL HARDWARE ELEMENT CHARACTERISTICS (CONT)

	PAYLOADS	PWR ⚠1 (kW)	WT ⚠1 (KG)	VOL ⚠1 (M^3)	POINTING ⚠3	TARGET
ST-22	CRYO-LIMB INTERFEROMETER RADIOMETER (CLIR)	0.18	850	2.83	10 $\widehat{S}$	LIMB
-23	FABRY-PEROT INTERFEROMETER	0.03	66	0.18	0.1°	– LIMB – ZENITH – NADIR
-24	WAVE INJECTION FACILITY				N/A	VARIOUS
	– ENERGY/MOM. INSTRUMENT	2.0-4.5	60-140	0.2-0.3		
	– IONOSPHERE MOD, INSTRUMENT (HF + X-BAND)	4.0-8.0	120-280	0.5-0.7		
	– VLF (1 Hz - 200 MHz) EXPERIMENT	2.0-4.5	2200-2800	11.0		
	– SUBSAT	N/A	1000-1500	16.0-24.0		
-25	HIGH PWR ELECTRON ACCELERATOR	1.8-5.0	525-1000	0.8 1.6	TBD	ALONG MAGNETIC FIELD OR VEL VEC
-26	HIGH PWR ION ACCELERATOR	1.8-5.0				
-27	HIGH PWR PLASMA ACCELERATOR	1.8-5.0				
-28	SOLAR OPTICAL TELESCOPE (SOT) FACILITY + EPM	2.0	4140	97.0	±1 $\widehat{S}$	SUN
-29	XUV FACILITY + EPM	0.13-2.0	2040-3000	25.0	±1 $\widehat{S}$	SUN
-30	SXR FACILITY + EPM	0.20-2.0	2220-3200	25.0	±1 $\widehat{S}$	SUN
-31	POLAR OPTICS	0.24	227	0.2	0.1 MIN	VARIOUS

SOLAR/TERRESTRIAL HARDWARE ELEMENT CHARACTERISTICS (CONT)

PAYLOAD		PWR 1 (kW)	WT 1 (kG)	VOL 1 (M^3)	POINTING 3	TARGET
ST-32	ATMOSPHERIC EMISSION IMAGER (VIS, UV, X-RAY; SEPARATE BOXES WITHIN PACKAGE)	0.80	450	1.5	0.5 $\widehat{M}$	BASIC-ALLY DOWN
-33	PLASMA SPHERE DYNAMICS PKG	0.05	30	0.05	1 $\widehat{M}$	NADIR
-34	3-D OZONE SCANNER	0.10	50	0.08	0.1 $\widehat{M}$	BASIC-ALLY DOWN
-35	IR SPECTROMETER PACKAGE	0.10	250	2.2	0.1 $\widehat{S}$	BASIC-ALLY DOWN
-36	FWD INCOHERENT SCATTEROM-ETER PROBE (FISP)	0.2	45	0.6 6	3.0 $\widehat{M}$	BASIC-ALLY DOWN
-37	EXPERIMENT POINTING MOUNT (EPM) 4	0.30	200	0.9	0.1 $\widehat{S}$	N/A

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ON-ORBIT DURATION DRIVERS

- This chart shows the general time scale, and the on-orbit vehicle or platform required to respond to solar atmospheric, magnetospheric and ionospheric events.

- Because of specialized Solar/Terrestrial payloads developed in the Solar/Terrestrial and Power Module studies, we can use knowledge gained from successful operation of the Solar/Terrestrial Observatory to provide continuity of scientific data.

ON-ORBIT DURATION DRIVERS — STO

DRIVER	DURATION	IMPLEMENTATION
• SOLAR PERIODS AND SOME SOLAR EVENTS — MINIMUM (ONE CONTINUOUS SOLAR REVOLUTION)	28 DAYS	• FREE-FLYER • SORTIE
• SEASONAL EFFECTS IN ATMOSPHERE, IONOSPHERE, MAGNETOSPHERE, SOLAR EVENTS	1 YEAR	• FREE-FLYER • MANNED CLUSTER
• LONG TERM SOLAR EVENTS ARE DYNAMIC AND NOT ALWAYS PREDICTABLE	1 - 3 YEARS	• MANNED CLUSTER
• SOLAR CYCLE EFFECTS (11-YEAR CYCLE)	1 - 3 YEARS	• MANNED CLUSTER

STO PAYLOAD REQUIREMENTS SUMMARY (ESTIMATED MAXIMUM)

- Presented on this chart is an overall summary of estimated maximum power and weight. There are two key driver parameters in the Part I study of Solar/Terrestrial payload requirements.

- The weights shown represent payload instruments only. When payload configurations and pallet mounting locations have been further developed, the payload special support structure and pallet weights can be added.

- Power figures include the payload plus Mission Dependent and Mission-Peculiar Equipment. Man-support (life support, etc.) is not included here.

- A range of power is shown for Increments 2 and 3. The higher number is the maximum sum of the average power of all individual payloads, assuming they are activated full time. On the basis of preliminary sequencing profiles, it appears that there may be a 25 to 30 percent reduction in power summaries. The smaller number, therefore, represents a reasonable minimum power requirement.

STO PAYLOAD REQUIREMENTS SUMMARY

(ESTIMATED MAXIMUM)

FLIGHT MODE	STAGE I (LEO) INCR NO. 1 1983			STAGE I (LEO) INCR NO. 2 1984			STAGE I (LEO) INCR NO. 3 1986			POLAR STAGE II 1988 ON			GEO STAGE III 1990 ON		
	WT (KG) [1]	PWR (kW) [2]	DUR	WT (KG) [1]	PWR (kW) [2]	DUR	WT (KG) [1]	PWR (kW) [2]	DUR	WT (KG) [1]	PWR (kW) [2]	DUR	WT (KG) [1]	PWR (kW) [2]	DUR
SHUTTLE-TENDED	4,200	9.5	30-90 DAYS	13,400	15 TO 20	30-90 DAYS	14,500	20 TO 28	30-90 DAYS						
UNMANNED FREE-FLYER	3000	9.5	1 - 2 YEARS	7,800	13 TO 18	1 - 2 YEARS									
MANNED FREE-FLYER PLATFORM							17,000	20 TO 28	1 - 3 YEARS	12,000	47	1 - 3 YEARS	18,000	50	1 - 3 YEARS

[1] INSTRUMENT WEIGHT ONLY

[2] ALL POWER INCLUDES PAYLOAD PLUS MISSION DEPENDENT AND MISSION PECULIAR EQUIPMENT POWER SUMMARIES; EXCLUDES MAN-SUPPORT POWER REQUIREMENTS

STO CONCLUSIONS

- It appears that a dedicated PM may be desirable early in Increment 2 (1984) to support the STO longer-duration free-flyer missions at 13 to 18 kW.

- Increment 3 manned platform in LEO also appears to merit assignment of a dedicated PM possibly a growth version. The man habitat increases the estimated 20 kW to about 37 kW total.

- The later manned platforms for Polar orbit and GEO will probably also require consideration of growth versions of the PM; each will require an estimated additional 17 kW (conservatively high) above the power summary shown on the chart for man-support functions.

- It appears that heat rejection can possibly be accommodated by integral radiators on the STO payloads (pallets and modules). This must be verified in follow-on studies.

- Because of the wide range of viewing and pointing/stability requirements for the STO payload groups, combined configurations of PM or PM/Orbiter and the payload-segments will require careful concept design consideration.

STO CONCLUSIONS

- PAYLOAD REQUIREMENTS FOR STAGES I AND II REASONABLY WELL DEFINED.
- REQUIREMENTS FOR STAGE III (GEO) ARE LESS WELL KNOWN BUT ADEQUATE TO SCOPE MISSION REQUIREMENTS.
- STO POWER AND DURATION REQUIREMENTS ARE KEY DRIVERS FOR POWER MODULE.
- 25 kW POWER IS REQUIRED TO SUPPORT EARLY SORTIE AND FREE-FLYER MISSIONS TO PROVIDE REQUIRED POWER LEVELS AND LONGER-DURATION ON ORBIT.

HIGHLIGHTS

• POWER REQUIREMENTS	– NEED DEDICATED PM FOR FREE-FLYER BY INCREMENT NO. 2 (1984)
• HEAT REJECTION	– ALL POWER USED REQUIRES MEANS OF DISSIPATION
• ASSEMBLY ON ORBIT	– SEPARATE INTEGRAL RADIATORS MAY BE REQUIRED. SOLAR POINTING PACKAGE ASSEMBLED TO PM: XUV FACILITY AND SXR ASSEMBLED TO SOLAR OBSERV FACILITY
• POINTING	– WIDE RANGE: SOLAR, ZENITH, NADIR, LIMB
• DURATION	– 30-90 DAYS SHUTTLE-TENDED; 1-3 YEARS FREE-FLYER (MANNED OR UNMANNED)
• MAN SUPPORT IN SPACE (FOR MANNED CLUSTERS OR SORTIES)	– PRESSURIZED MODE – OBSERVATION, ADJUSTMENT – EVA – MAINTENANCE OF PAYLOAD

OTHER PAYLOAD DISCIPLINES

- ASTROPHYSICS/ASTRONOMY
- EARTH OBSERVATION
- SOLAR POWER SATELLITE
- LIFE SCIENCE

PM IMPACT OF ASTROPHYSICS/ASTRONOMY PAYLOADS

- Most of these payloads have been conceived to date to be free-flyers supported by mission-peculiar spacecraft. Some exceed the Orbiter cargo bay volume and must be assembled on orbit.

- The orbit of most of the payloads is essentially compatible with the probable operating orbit of the PM, either at 50 to 57 deg or at 28.5 deg inclination. This offers the feasibility of mounting one or more of these payloads on a multidiscipline platform with other payloads. Because of the normally low (2 to 3 kW) power requirement for these payloads, a dedicated PM for a single payload does not appear desirable. MSFC is currently investigating mounting of one or more telescopes on a multidiscipline platform to be supported by the PM.

- In general, the principal PM-drivers are long-duration observation times and low-contamination environment (the latter accomplished with use of CMGs in lieu of expulsion-type ACS).

PM IMPACT OF ASTROPHYSICS/ASTRONOMY PAYLOADS

GENERAL

- SIZE – PAYLOADS ARE LARGE, SOME REQUIRING ASSEMBLY OF SEGMENTS IN LEO
- FREE-FLYER – MOST DESIGNED AS FREE-FLYERS; CONVERSION POSSIBLE TO PLATFORM MOUNT
- DEDICATED PM – NOT REQUIRED; POSSIBLE MULTI-DISCIPLINE PLATFORM APPLICATION
- ORBIT – LOW INCLINATION, 28.5 TO 57 DEG, FOR MOST PAYLOADS
- PM DRIVERS – NO PRIMARY DRIVER REQUIREMENTS; DURATION IS SECONDARY DRIVER

PM SUBSYSTEM IMPACT

- POWER – LOW: APPROXIMATELY 2-3 kW
- POINTING – INERTIALLY OR CELESTIAL ORIENTED; 0.1 TO 1800 ARC SEC; INTEGRAL GIMBAL MOUNTS
- DURATION – LONG VIEWING TIMES; 30 DAYS TO 10 YEARS
- HEAT REJECTION – NOT REQUIRED; INTEGRAL WITH PAYLOAD (RADIATION)
- DATA PROCESSING – DATA RATES BASICALLY LOW – KBPS RANGE
- CONTAMINATION – CRITICAL ON MOST PAYLOADS
- MAN SUPPORT – NOT CRITICAL EXCEPT FOR REVISIT; GROUND CONTROL LOOP APPEARS ADEQUATE

ASTROPHYSICS/ASTRONOMY (AA) PAYLOAD CHARACTERISTICS

- This chart lists characteristics of a number of payloads planned for launch in the period 1984 to 1995. Several are listed in the NASA 5-year Plan. The priorities on these programs are frequently changing; therefore, this listing is offered only as representative of the AA-type payloads that may be funded in subsequent years. From these, some may be selected for mounting on multidiscipline platforms.

- Payloads AA-6, -7, and -9 were initially conceived as flying on Spacelab missions mounted on an Instrument Pointing System (IPS) in the Orbiter. These, or others, may be convertible to placement on free-flyer platforms supported by the PM.

- AA-4 (detail shown on the following chart) is a NASA version of an AA pallet group which could be flown attached to the Skylab or as a free-flyer cluster.

- The Gamma Ray Observatory (AA-8) possibly also could be converted from its current mission-peculiar spacecraft to a platform mounted arrangement.

ASTROPHYSICS/ASTRONOMY (AA) PAYLOAD CHARACTERISTICS (TYP)

PAYLOAD NO.	PAYLOAD NAME	ORBIT (KM/DEG)	MISSION DURATION	IOC DATE	MASS (KG)	POINTING ACCURACY (DEG)	POWER (kW)
AA-1	ADVANCED X-RAY ASTROPHYSICS FACILITY (AXAF)	450/28.5	5-10 YR	1984-1985	10,000	30	2
AA-2	NATIONAL X-RAY OBSERVATORY (NXO)	430/28.5 650/0	10-20 YR	1990-1995	25,000	0.1	2
AA-3	VERY LARGE SPACE TELESCOPE (VLST)	426/28.5	10-20 YR	1990-1995	22,800	20 TO 30	3
AA-4	ASTROPHYSICS/ASTRONOMY (AA) PALLET GROUP (SKYLAB OR FREE-FLYER)	430/50 430/28.5	30-90 DAYS	1984-1985	7,784	10 TO 30	2
AA-6	CRYO-COOLED IR TELESCOPE FOR SPACELAB (CIRTS) (1.6 M PRIMARY MIRROR)	430/28.5	30 DAYS	1986-1990	8,500	IPS MOUNTED	3
AA-7	STARLAB (1-M APERTURE) (SPACELAB)	430/28.5	30-90 DAYS	1986-1990	2,000	IPS MOUNTED	2
AA-8	GAMMA RAY OBSERVATORY (GRO)	430/28.5	1 YR	1983	6,500	30	2
AA-9	LARGE IR TELESCOPE FOR SPACELAB (LIRTS) (2.8 M PRIMARY MIRROR)	460/28.5 350/57	30 DAYS	1983-1984	3,785	IPS MOUNTED	3
AA-10	LAMAR (4 D X 8 M)	500/28.5	2 YR	1988	12,000	30	2
AA-11	COSMIC RAY OBSERVATORY	400/50	5 YR	1986	15,000	1 DEG	2

TYPICAL ASTROPHYSICS/ASTRONOMY PALLET GROUP (AA-4)

- This chart provides the characteristics of a typical pallet grouping of AA-type individual payloads. The collection was developed by GSFC for Orbiter/Spacelab and proposed as a possible payload group to be used in conjunction with Skylab in 1984 – 1985.
- The primary characteristics, if such an arrangement were to be supported by a PM, are the pointing accuracy (coupled with low-contamination CMGs) and the mission duration of 30 to 90 days.
- The payloads can be made capable of remote control from the ground but revisit would be required for instrument recheck, camera unload/load, etc. The payloads as initially planned were for man-support on Spacelab missions.

TYPICAL ASTROPHYSICS/ASTRONOMY PALLET GROUP (AA-4)

MISSION PURPOSE: WIDE-FIELD SKY SURVEYS PLUS NARROW FIELD INVESTIGATIONS OF SPECIFIC STARS, NEBULAE, QUASARS, GLOBULAR CLUSTERS

CONCEPT DESCRIPTION: PALLET-MOUNTED PAYLOAD GROUP, ATTACHED TO SKYLAB OR EQUIV PLATFORM

SUPPORT REQTS:

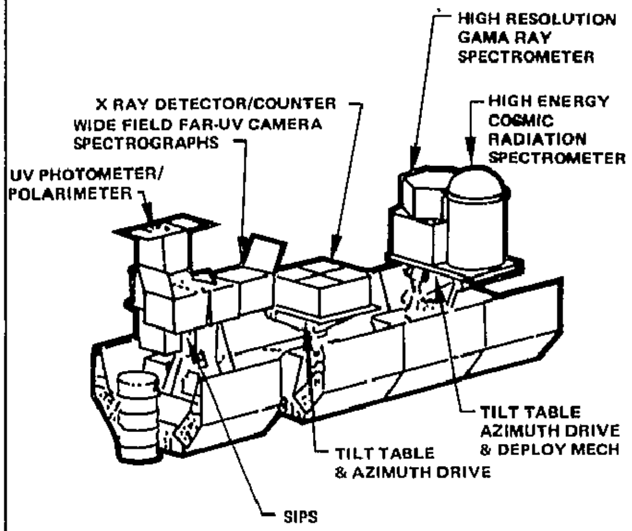
• WEIGHT, kg	7800
• SIZE, m	Up To 5 Pallets
• POWER REQD.	850W To 2kW
• POINTING ACCUR OR G	10 Arc Sec To 30 Arc Sec
• P/L DATA HDLG	480 kbps
• THERMAL CONTROL METHOD	None Special
• ORBIT, km/deg	430/50
• IOC TIME FRAME	1984 - 85
• MISSION DURATION	30 To 90 Days

DEVELOPMENT/OPERATION REQTS:

- KEY TECHNOLOGY DEVEL
- TRANSPORTATION
- ON-ORBIT OPERATIONS
- MAN-SUPPORT Monitor/Control; Either On-Orbit or Remote From Ground With Revisit
-

COMMENTS: ⚠ SIPS or IPS Provide Fine Pointing

PAYLOAD ILLUSTRATION:



- Telescopes-UV, X-Ray, Gamma, Cosmic R&D
- Polarimeters
- X-Ray Detectors
- Radio Telescopes
- Cameras

REFERENCE: GSFC "Astrophysics Payloads for Spacelab Summary Report", October 1976

PM IMPACT OF EARTH OBSERVATION PAYLOADS

- A general summary of the characteristics of Earth Observation (EO) payloads and their potential impact upon PM design is shown on the chart. These payloads generally represent a class initially conceptualized for free-flying with mission peculiar spacecraft. However, if the orbit requirement, which ranges from 50 to 57 deg to sun-synchronous, can be modified to be compatible with other discipline payloads, an EO payload can be mounted on a multi-discipline payload platform; GEO platform mounting may also be feasible.

- The power required for most EO single payloads is moderately low because of passive device instrumentation. If active instruments, such as synthetic aperture radar, are used, the power levels may increase to as high as 10 to 20 kW.

- Some of the payloads require high data rate downlink transmission, in the MBPS range; most are planned as unmanned free-flyers.

- Pointing is nadir and separate payloads will not require special accuracy stabilization if each can be gimbal mounted.

- In general, EO payloads principal PM drivers are long-duration observation times and in cases where active-element payloads are utilized, a potential power driver (up to 20 kW). More investigation of these payloads is required for use on multidiscipline platform supported by a PM.

PM IMPACT OF EARTH OBSERVATION PAYLOADS

GENERAL

- SIZE/MASS – NORMALLY WILL NOT REQUIRE ON-ORBIT ASSEMBLY
- FREE-FLYER – MOST ARE FREE-FLYER CONCEPTS; ADAPTABLE TO PLATFORM MOUNTING
- DEDICATED PM – MAY BE DESIRABLE FOR ACTIVE-ELEMENT PAYLOADS (RADAR)
- ORBIT – HIGHER-INCLINATION LEO AND GEO
- PM DRIVERS – MISSION DURATION, POINTING, POWER

PM SUBSYSTEM IMPACT

- POWER – 1 TO 20 kW
- POINTING – NADIR-ORIENTED; 6 ARC SEC TO 0.5 DEG; SOME PAYLOADS CAN USE INTEGRAL GIMBAL MOUNTS
- DURATION – 1 TO 10 YEARS. CAN BE OPERATED WITH SCHEDULED ON-OFF CYCLES
- HEAT REJECTION – SOME MAY BE REQUIRED (TBD)
- DATA PROCESSING – SOME PAYLOADS REQUIRE HIGH DATA RATES – MBPS RANGE
- MAN SUPPORT – NOT REQUIRED ON ORBIT

EARTH OBSERVATION PAYLOAD CHARACTERISTICS (TYPICAL)

- This chart lists the principal characteristics of a group of Earth Observation (EO) payloads investigated in this study, with the launch dates covering a period 1984 to 1995. The funding of many of these programs is not yet firm; they are therefore offered as representative of the larger EO payloads which may influence PM support activity in the future. None was studied in depth because of resources constraints in the Part I study.

- All payloads listed are currently planned as unmanned free-flyers with the exception of the EO-2 mission, which is envisioned as a potential NASA Skylab-supported (man-support) grouping of payloads, using a Shuttle-tended mode with intermittent operation of the payloads. A PM could be substituted if a larger complement of payloads could be added to raise the total power requirement and allow longer orbit operational periods between revisits.

- A single payload group, EO-1, offers an interesting payload grouping which might use a PM (or elements thereof) as a dedicated support spacecraft because of the 20 kW power requirement.

- Some clustering of EO payloads is probably desirable on multidiscipline platforms; for example EO-5 or EO-6 could be placed on a geostationary platform.

EARTH OBSERVATION PAYLOAD CHARACTERISTICS (TYPICAL)

PAYLOAD NO.	PAYLOAD NAME	ORBIT (KM/DEG)	MISSION DURATION (YEARS)	IOC DATE	MASS (KG)	POINTING ACCURACY (DEG)	POWER (kW)
EO-1	ADVANCED EARTH RESOURCES/POLLUTION OBSERVATION • SYNTH APERT RADAR • MULTI-SPECTRAL TELESCOPE • SEVERAL SMALL SENSORS	500-900/ SUNSYNC	3-5	1985	15,000	0.05	20
EO-2	MULTI-SENSOR ATMOSPHERIC SCIENCE AND EARTH OBSERVATION • RADIOMETERS • SPECTROMETERS • INTERFEROMETERS • CAMERAS • LIDAR	450/50 SKYLAB-SUPPORTED	3-5	1984	1,500	0.005 TO 0.5	4
EO-3	HIGH-RESOLUTION EARTH RADIOMETER • 100 D X 120 M OFFSET PARAB ANTENNA; 1.4 TO 300 KHz	400 SUNSYNC	5 + (REFUEL YEARLY)	1987	50,000	0.005	5 TO 10
EO-4	ATMOSPHERIC TERMPERATURE PROFILE SOUNDER • PULSED RADAR • 10-M DIAMETER ANTENNA	1100	5 +	1990	2,000	0.1	5
EO-5	ADVANCED METEOROLOGICAL SATELLITE • 1 M VISUAL OPTICS • 90 M RESOLUTION (COULD BE MOUNTED ON EO-6 OR GEO STATIONARY PLATFORM)	GEO	5 +	1985	1,500	0.01	1
EO-6	ADVANCED MULTI-SENSOR EARTH OBSERVATION PLATFORM • MULTISPECTRAL OPTICS • LASER ATMOSPHERE SOUNDER • RADIOMETER AND SPECTROMETER • LIDAR	GEO	10 +	1995	10,000 TO 20,000	0.002 TO 0.5	10 TO 20

ADVANCED EARTH RESOURCES/POLLUTION OBSERVATORY (EO-1)

- The configuration shown on this chart is representative of an Earth Observation (EO) payload grouping that could utilize a derivative of the 25 kW PM. It generally illustrates payload types which may be attached directly to the PM rather than attached as separate pallets or modules.

- It is possible that this configuration could be operated in another orbit plane, such as 57 deg, if coverage of the CONUS areas only were acceptable. This would provide more effective usage of the PM sun-orienting solar arrays.

- The payload data handling, in the range of 500 MBPS, could be accommodated by a payload-peculiar C&DH package and antenna.

- This payload grouping is controllable from the ground but would probably require some initial assembly on orbit and should be designed for revisit-maintenance by the Orbiter.

ADVANCED EARTH RESOURCES/POLLUTION OBSERVATORY

MISSION PURPOSE: TO PROVIDE HIGH-QUALITY MULTI-SPECTRAL EARTH RESOURCES AND POLLUTION DATA

CONCEPT DESCRIPTION: ACTIVE AND PASSIVE SENSORS IN SUN-SYNCHRONOUS LOW EARTH ORBIT AND WIDE-BAND DATA LINK TO GROUND VIA GEO RELAY SATELLITE

SUPPORT REQTS:

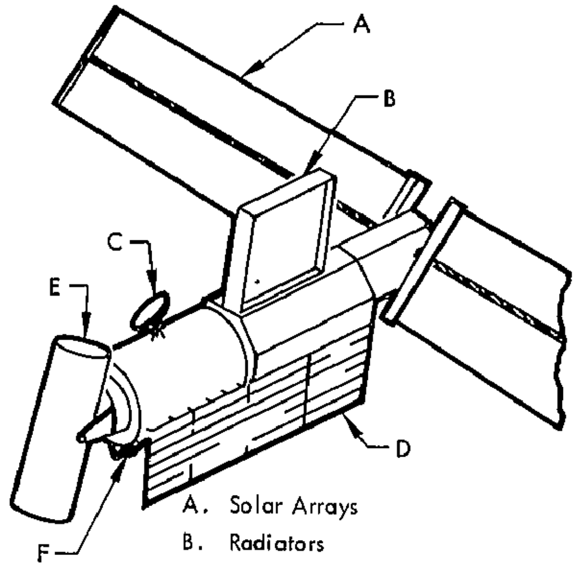
• WEIGHT, kg	15,000
• SIZE, m	3 Dia. x 15 plus Sensors
• POWER REQD.	20kW
• POINTING ACCUR OR G	0.05 Deg
• P/L DATA HDLG	500 MB/S Via Relay Sat.
• THERMAL CONTROL METHOD	Coldplate & Radiators 15 kW
• ORBIT, km/deg	500 to 900 KM, Sun-Synch.
• IOC TIME FRAME	1985 - 1987
• MISSION DURATION	5 to 10 yr.

DEVELOPMENT/OPERATION REQTS:

- KEY TECHNOLOGY DEVEL Sensors, Wide-Band Relay, LEO Assy.
- TRANSPORTATION STS
- ON-ORBIT OPERATIONS Assy. & Test
- MAN-SUPPORT LEO Assy. & Test
-

COMMENTS:

PAYLOAD ILLUSTRATION:



A. Solar Arrays
B. Radiators
C. Data Link Antenna
D. Synthetic Aperture Radar Antenna
E. Multispectral Telescope
F. Spectrometers, Radiometers, etc.

Missions:

- Resources Survey
- Land Use Monitor
- Ocean Dynamics
- Weather & Climate Monitor
- Environmental Quality
- Monitor

REFERENCE: Space Indust. Study, Part 1, SAI, 4/77

SOLAR POWER SATELLITE (SPS) DATA REVIEW

- Many studies have been completed on the SPS; many are still in work. Only recently, DOE and NASA have agreed upon shared assignments in initiating a consolidated program. The basic requirements of the program are very dynamic and will probably continue to change for some time; the payload hardware specifics are therefore also subject to large changes.

- LMSC reviewed a large quantity of documents on the proposed SPS development and configuration but was unable to find a common thread of correlation which could at this time support definitive requirements for growth of the PM. It was therefore agreed with MSFC to omit further specific derivation of SPS requirements as drivers for the PM.

- However, as a consolidated scenario for the SPS development in LEO and GEO develops and is approved by NASA/HQ and MSFC, the SPS may be a very important driver for growth versions of the PM.

SOLAR POWER SATELLITE (SPS) PAYLOADS DATA REVIEW

PRINCIPAL DATA ANALYZED

- NASA/HQ 5-YEAR PLAN
- RI SPACE INDUSTRIALIZATION STUDY
- SAI SPACE INDUSTRIALIZATION STUDY
- GRUMMAN ORBITAL CONSTRUCTION DEMONSTRATION STUDY
- GRUMMAN SPACE STATION STUDY
- JSC SATELLITE POWER SYSTEM CONCEPT EVALUATION PROGRAM
- BOEING DOCUMENTS ON SOLAR POWER SATELLITE
- BOEING FUTURE SPACE TRANSPORTATION SYSTEMS ANALYSIS STUDY
- RI SPS CONCEPT DESIGN STUDY (PRELIMINARY DRAFT)

REVIEW CONCLUSIONS

- CONCEPTS VARY OVER A WIDE RANGE OF SIZE AND COST
- DEVELOPMENT STEPS FOR A CONSOLIDATED PROGRAM VARY WIDELY
- THE SPS APPEARS TO BE A KEY DRIVER FOR THE EARLY POWER MODULE, PRIMARILY SUPPORTING ASSEMBLY AND TEST OF PRECURSOR DEVELOPMENT HARDWARE IN LEO AND LATER ASSEMBLY/TEST OF GEO SEGMENTS IN LEO

SPS DEVELOPMENT SCENARIO — ALTERNATIVE 1

- This chart (and the one following) shows a typical scenario for development of the initial 5 GW SPS operating in GEO. It has been generally excerpted from informal and preliminary data of a study being done for MSFC by RI. (Changes may be made before the RI study is complete.)

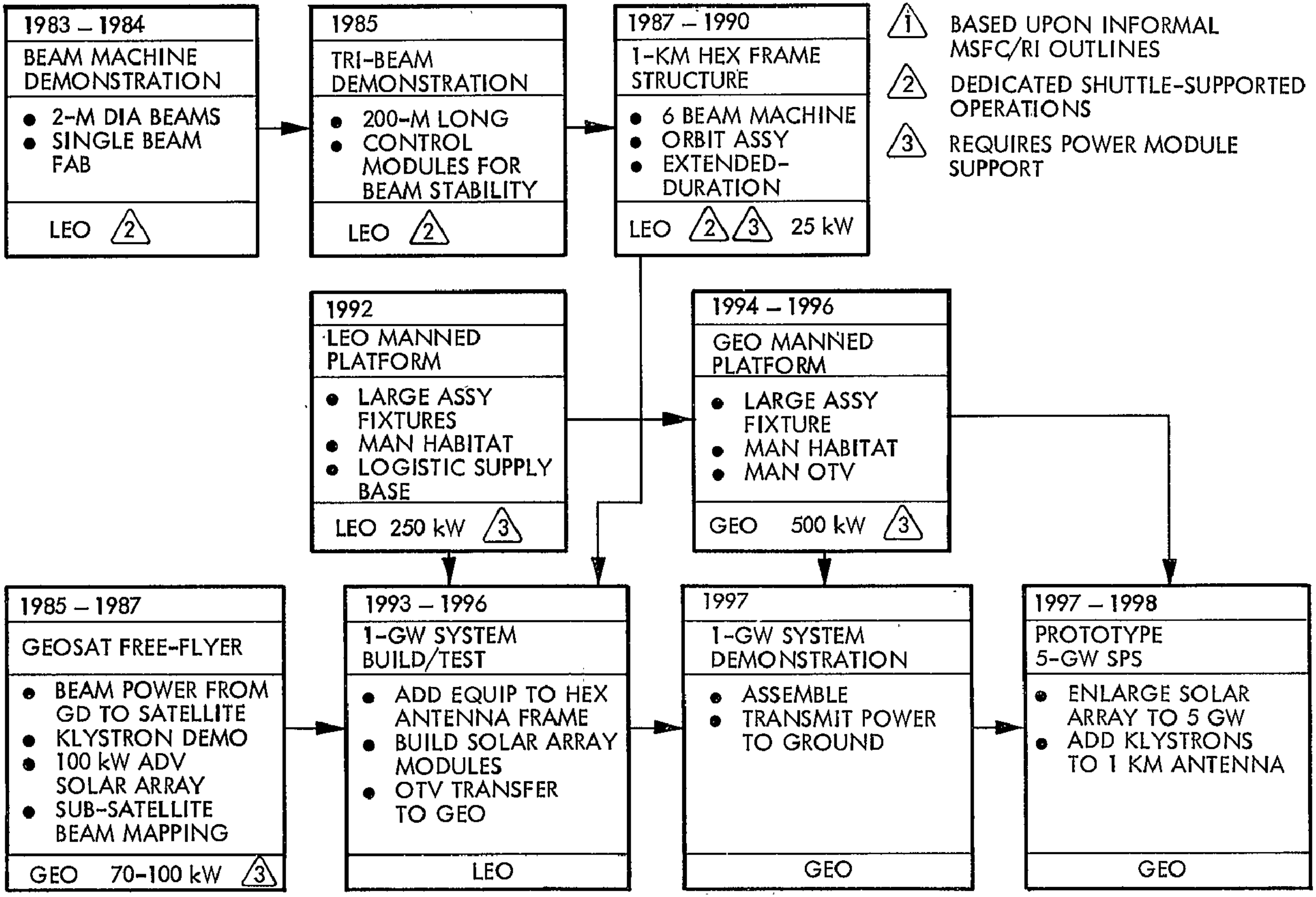
- The development activity starts in 1983 in LEO with 2-meter beam-machine fabrication; these orbit operations continue in LEO for development/test of 50-meter cross-section tri-beams and eventual construction of the one kilometer hex-frame structure for the microwave antenna. All of these operations are Shuttle-supported and by 1987 (or earlier) 25 kW PM support is required also.

- Construction of a LEO manned platform (at 28.5 deg inclination) becomes necessary in 1990-1992 for pre-assembly of large submodules of the GEO Solar Array and to provide a logistics base. 250 kW has been proposed to support this base.

- One interesting feature of this scenario is the use of a manned GEO platform earlier than other payload missions (1994-1996) to perform larger assembly, system demonstration, and enlarging the GEO system from 1 GW to the 5 GW capability. This platform has been estimated by MSFC/RI to require 500 KW support.

- If this type of scenario becomes a firmer requirement, it will establish an additional strong basis for growth versions of the PM.

SPS DEVELOPMENT SCENARIO — ALT. 1 1



SPS PAYLOAD DEVELOPMENT SCENARIO – ALTERNATIVE 2

- A more modest scenario than that shown in previous Alternative 1 does not include a GEO manned platform. It differs in potentially requiring 25 kW PM support in LEO as early as 1983 to assist in construction of initial GEO SPS solar array segments. This scenario is an LMSC modification of an earlier Aerospace Corporation proposal of June 1977.

- The LEO operations increase by 1990 to a manned large construction platform whereon is built and tested a prototype solar array (90 by 1600 meters) and a 100 meter diameter microwave antenna. An estimated 100 kW PM is required to support these operations. The completed units are moved to GEO by Orbit Transfer Vehicle (OTV) for demonstration of 10 megawatt transmission to ground receiver.

- By 1995 the operations in LEO are enlarged for construction of the larger solar array and larger microwave antenna. These manned-platform operations are estimated to require a 200 kW PM for support.

- In general, this scenario develops faster than the one shown on Alternative 1 previously but the power requirements for manned platform support are lower.

SPS PAYLOAD DEVELOPMENT SCENARIO – ALT. 2 ⚠1

	CONCEPT DEMONSTRATION	TECHNOLOGY DEMONSTRATION	PRECURSOR OPERATIONS	OPERATIONAL SPS
	1983	1986	1990	1995
	LEO ASSY/TEST	LEO ASSY/TEST	LEO ASSY/TEST	LEO ASSY/TEST
	SOLAR ARRAY • 45 X 100 M • 500 kW	SOLAR ARRAY • 45 X 400 M • 2 MW	SOLAR ARRAY • 90 X 1600 M • 20 MW	SOLAR ARRAY • 2 X 21 KM • 1-5 GW
	MW ANTENNA • 8 X 8 M • 350 kW XMTR	MW ANTENNA • 16 X 16 M • 1.5 MW XMTR	MW ANTENNA • 100-M DIA • 15 MW XMTR	MW ANTENNA • 1 KM DIA • 0.8 – 4 GW
	15 kW ⚠2	15 kW ⚠2	75 kW ⚠2	150 kW ⚠2
		GEO OPS 1.0 MW USEABLE POWER ON GROUND	GEO OPS 10 MW USEABLE POWER ON GROUND	GEO OPS 0.6 – 3 GW USEABLE ON GROUND
SUPPORT ELEMENTS	• SHUTTLE • 25 kW POWER MODULE • SMALL CONSTRUCTION PLATFORM	• SHUTTLE • 25 kW POWER MODULE • SMALL CONSTRUCTION PLATFORM • OTV	• MAN HABITAT (LEO) • 100 kW POWER MODULE • LARGE CONSTRUCTION PLATFORM • OTV	• MAN HABITAT (LEO) • 200 kW POWER MODULE • LARGE CONSTRUCTION PLATFORM • OTV

⚠1 MODIFICATION OF AEROSPACE CORP., SCENARIO, JUNE 1977

⚠2 REQUIRES POWER MODULE SUPPORT

IMPACT OF SPS PAYLOADS ON PM

- The general features of the SPS development program consolidated from review of several NASA concept studies, are listed on this chart. Although the SPS development plans are still dynamic, it appears that the SPS requirements should be reviewed when they have been further firmed to ascertain potential impact on the PM growth versions.

- The SPS development is a long-term operation and may require a dedicated PM (one or more). The power levels required from the PM vary considerably; however, it appears that a 25 kW PM may be required as early as 1983 – 1984 to start LEO construction and testing. Power to support large construction platforms will range from 200 kW to 500 kW, dependent upon the extent of automation, quantity of man-support, and the division of assembly/ test between LEO and GEO. The earliest date for a platform in LEO appears to be about 1986.

- Because of the special PM driving features of the SPS program, separate in-depth study should be devoted to establishing in the near future a single development program aimed at identifying specific requirements for the PM.

IMPACT OF SPS PAYLOADS ON PM

GENERAL

- SIZE – PAYLOADS ARE VERY LARGE; REQUIRE CONSTRUCTION PLATFORMS IN LEO AND GEO
- DEDICATED PM – MOST SPS CONCEPTS WILL REQUIRE ONE OR MORE
- ORBIT – INITIAL PROTOTYPE ASSEMBLY/TEST IN LEO, 28.5 DEG
  – FINAL ASSEMBLY/TEST IN GEO
- ORBIT TRANSFER – PM MAY BE USED FOR ION THRUSTER POWER

PM SUBSYSTEM SUPPORT

- POWER

	LEO	IOC	GEO
– SORTIE	25 kW	1983-1984	–
– PLATFORM	25-100 kW	1986-1987	75-125 kW GEOSAT
– PLATFORM	200-300 kW	1988-1992	200-500 kW PLATFORM

- POINTING – CONTROL OF LARGE FLEXIBLE ASSEMBLIES
- DURATION – ASSEMBLY OPERATIONS OF LONG DURATION – MINIMUM 30-DAY INCREMENTS
- HEAT REJECTION – NOT REQUIRED FOR PAYLOADS
- DATA PROCESSING – DATA RATES LOW
- MAN SUPPORT – REQUIRED FOR ALL LARGE ASSEMBLY; EITHER SHUTTLE SORTIE OR MAN HABITAT; EVA REQUIRED.
  – 100-MAN SUPPORT IN LEO

POWER REQUIRED FOR LIFE SCIENCES PAYLOADS

- The Life Sciences discipline was reviewed generally. The data on the chart (from MSFC) appear to be correlated with recent summary data from NASA/HQ.

- The initial Life Sciences module will probably be combined with other payloads on a manned platform ; possibly with Solar/Terrestrial on an early manned platform. The power requirement of 7 kW in 1986 is not by itself a driver but mission durations longer than the Orbiter Sortie missions are desirable, 60 to 90 days.

- Pharmaceutical materials production has been included in the Materials Processing in Space (MPS) section of this report. As with MPS, the prime requirement is low g force.

- The principal PM driver for early missions is longer duration on orbit. For later missions (1990 and beyond) the power levels will strongly influence the total for a manned platform when Life Science modules are included. Totals of 25 to 40 kW may be required if both the module and laboratory are used.

POWER REQUIRED FOR LIFE SCIENCE PAYLOADS ⚠1 ⚠2

LIFE SCIENCES EXTENDED MISSION MODULE (LSEMM)

- IOC – 1986
- ON MANNED PLATFORM
- POWER REQUIRED – INITIAL LSEMM – 7 kW (1986)
  – GROWTH LSEMM – 15 kW (1990)

QUARANTINE/RESEARCH LAB (PLANETARY RETURN SAMPLES)

- IOC – 1990
- ON MANNED PLATFORM
- POWER REQUIRED – 10 TO 25 kW

⚠1 DOES NOT INCLUDE POWER FOR CREW SUPPORT; CREW VARIES FROM 2 (1985) to 8 (1990)

⚠2 REF: HILCHEY, MSFC 5/9/77

MULTI-DISCIPLINE PAYLOAD APPLICATIONS

- CONCEPT
- TYPICAL PLATFORMS
- COMMONALITY FEATURES
- CONSTRUCTION OF LARGE PLATFORMS

CONCEPTS OF MULTIDISCIPLINE PAYLOAD GROUPING

- The concept of combining payloads from two or more payload disciplines is cost effective for application of the PM. It must be assumed, of course, that the payloads can be operated in the same orbit location and that the field-of-views, orientation, and attitude control requirements are compatible. It is possible that a single larger PM is more economical than two or more smaller-capability PMs; these alternatives must be traded-off, considering the quantity of Shuttle revisits and other parameters listed on the chart. The results may prove that dedicated PMs are more desirable and more flexible in orbit operation, particularly when certain separate disciplines can saturate the capability of a single power module, either on an orbit-orientation basis (Solar/Terrestrial) or on a power basis (Materials Processing or SPS).

- The multidiscipline platform application is a viable concept, however, and should be pursued strongly both within NASA and perhaps by industry studies. MSFC is currently concept-designing initial approaches for science (OSS) payloads and may later expand the concept scope to include both development and operational payloads (OSTA).

CONCEPTS OF MULTI-DISCIPLINE PAYLOAD GROUPINGS

APPLICATION OF CONCEPT

- PROVIDE COMMON SUPPORT FOR TWO OR MORE PAYLOAD DISCIPLINES
  - POWER
  - COARSE POINTING (OR TIME-SEQUENCED FINE POINTING)
  - DATA PROCESSING
  - HEAT REJECTION
- REQUIRE FEWER SHUTTLE REVISITS (SINGLE ORBIT RENDEZVOUS)
  - MATERIEL SUPPLY/PRODUCT PICKUP
  - MAINTENANCE
  - PERSONNEL ROTATION
- FEWER PERSONNEL ON MANNED PLATFORMS – SHARING FUNCTIONS
- SINGLE POWER MODULE IN LIEU OF SEVERAL INDEPENDENT ONES

FORMS OF PAYLOAD GROUPINGS

• SINGLE PALLET • PALLET CLUSTER • MODULE CLUSTER • MODULE/PALLET CLUSTER • LARGE PLATFORM	• UNMANNED • MANNED

POTENTIAL NASA MULTIDISCIPLINE PLATFORMS FOR PM SUPPORT

- This chart tabulates estimated power requirements for two MSFC multidiscipline payload platform concepts. The one for LEO is newly conceived, basically for science (NASA/OSS) payloads; work is being directed from Jim Ballance's Physics and Astronomy office. The Geostationary Platform is a concept, initially to be operated as a large communication platform; its concept development is under the responsibility of Ted Carey.

- The OSS platform candidate disciplines are listed; however, these are intended to be supplemented by Earth Observation and Materials Processing payloads as platform capability matures. OSS does not plan to build and operate their own platform. The initial platform, comprising a small pallet train supported by a PM in 1983 is planned for operation in several alternate LEO inclinations and could possibly saturate the power capability of a 25 kW PM. Progressive steps of implementation extend the concept to a large (beam-machine constructed on orbit) platform in 1990 which would require power ranging from 50 kW to 200 kW.

- The Geostationary Platform concept has a requirement for construction in LEO and operation in GEO in 1986; it can utilize a GEO PM of up to 40 kW capability. Later, additional plug-in modules for other payload disciplines could be added. Its configuration is shown on a later chart.

POTENTIAL NASA MULTI-DISCIPLINE PLATFORMS FOR PM SUPPORT

	ORBIT	CANDIDATE DISCIPLINES 3	CONFIGURATIONS	IOC	POWER REQUIRED (kW)
OSS MULTI-DISCIPLINE PLATFORM(S) 1 • UNMANNED • FREE-FLYER • SHUTTLE REVISIT	LEO 2	• ASTRONOMY • SOLAR PHYSICS • ATMOSPHERIC/ MAGNETOSPH. • LIFE SCIENCE • PLANETARY SPACECRAFT ASSEMBLY	• SMALL PALLET TRAIN (3) • LARGE PALLET TRAIN (9) • SMALL PLATFORM (PLUG-IN PAYLOAD MODULES) • LARGE PLATFORM (BEAM MACHINE)	1983 1985 1986 1990	15-25 25-50 25-100 50-200
GEOSTATIONARY PLATFORM 1 • UNMANNED • ASSEMBLED IN LEO	GEO	• PUBLIC SERVICES • EARTH OBSERVATION • SOLAR/ TERRESTRIAL	• LARGE COMMUNICATION PLATFORM • PLUG-IN PAYLOAD MODULES	1986 1990	20-40 50

1 PRELIMINARY MSFC DATA

2 VARIOUS INCLINATIONS; 28.5, 57, POLAR, SUN-SYNC.

3 EARTH OBSERVATION AND MATERIALS PROCESSING MAY BE ADDED.

NEAR-TERM MULTIDISCIPLINE PLATFORMS – LEO

- This chart illustrates two concepts for a multidiscipline platform in LEO in the 1983 to 1986 period: (1) a man-supported arrangement on the left and (2) a free-flyer on the right. Both include combined Materials Processing and Solar/Terrestrial payload pallets/modules. Exact configuration is not intended to be represented nor is the quantity of payload pallets or modules.

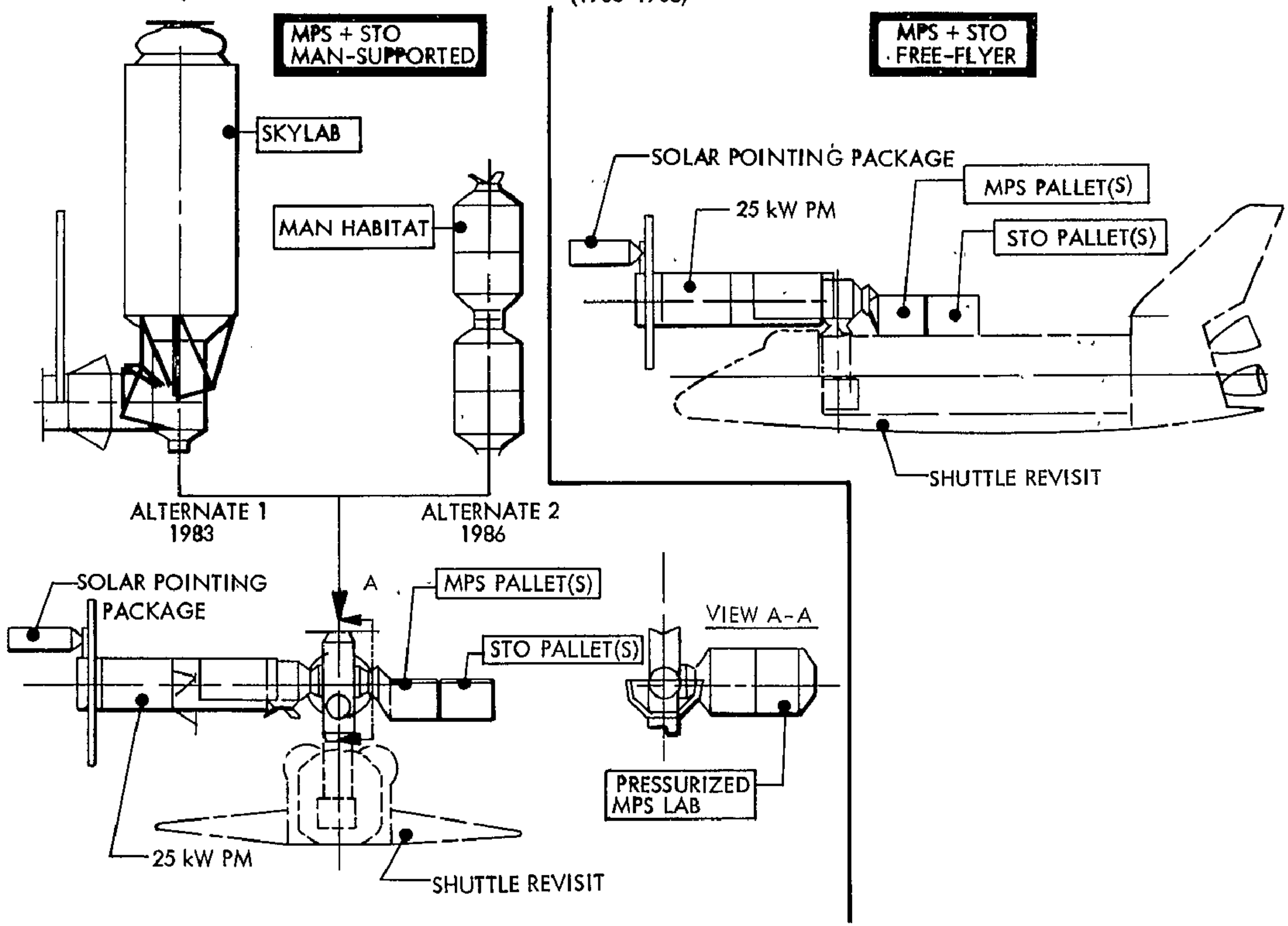
- In both cases, the 25 kW PM provides common support for the payloads and the man-habitats. As mentioned on previous charts, this basic configuration could grow and require considerably more power, ranging up to 50 kW by 1986.

- For the man-supported version, a central multiple-docking module is required to connect payloads and support elements; the Orbiter can dock to it for periodic revisits. The Skylab alternate could be used as early as 1983; the new man-habitats probably not until 1986.

- The free-flyer configuration on the right is somewhat unlimited in growth capability by addition of pallets in single or multiple trains, attached to a single PM docking adapter. Structural flexibilities and loads from orbital maneuvering may become critical in the larger pallet/module "cluster" and should be verified as specific concept configurations become available in forthcoming studies of multidiscipline platforms.

NEAR-TERM MULTI-DISCIPLINE PLATFORMS - LEO

(1983-1986)



MULTI-DISCIPLINE GEOSTATIONARY PLATFORM

- This chart shows essentially a duplicate configuration of that shown previously as a Public Services communication platform in GEO. In concept, this platform would be placed in GEO in 1986 with multiple communications antennas.* Its initial weight, without a PM, would be about 6500 kg.

- The 40 kW GEO PM shown has a solar array area about the same as that of the LEO 25 kW PM. Reduced complements of batteries and radiators would be required. The 40 kW would allow for growth by later additions of other payloads, meteorological and environmental observation (Earth Observation) and perhaps some Solar/Terrestrial instruments. Mass could also grow up to an estimated 15,000 kg by addition of the plug-in type payload modules, delivered in the early 1990s.

- Initial delivery to GEO is planned by chemical and/or ion propulsion OTV units in 1986. Delivery of add-on units later may be made by remote-control OTV combined with Teleoperator (plan not yet firm).

*And possibly with some earth observation sensors.

MULTI-DISCIPLINE GEO STATIONARY PLATFORM

CHARACTERISTICS

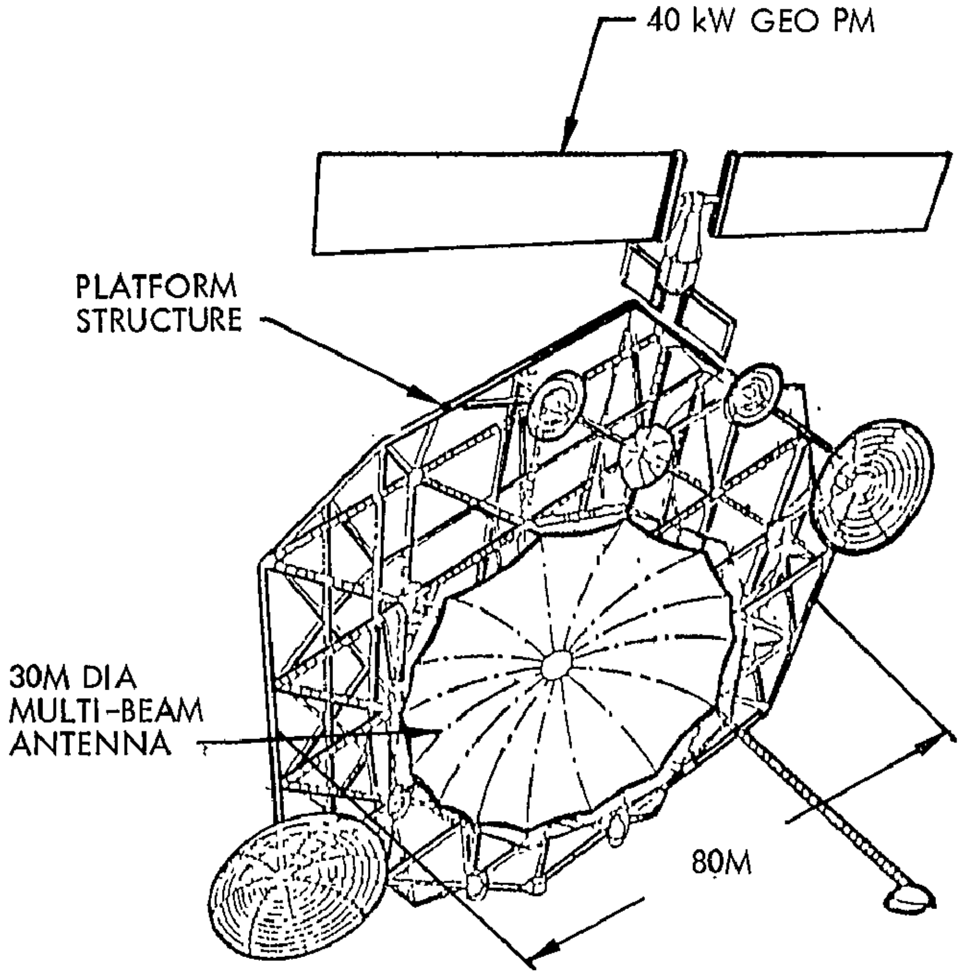
- WEIGHT: 6500 - 15000 KG ⚠1
- POWER REQUIRED: 20 kW TO 40 kW
- POINTING ACCURACY: 0.5 DEG
- IOC DATE: 1986 - INITIAL
  1990 - ADD-ONS

CANDIDATE MISSIONS

- COMMUNICATION SATELLITE
- METEOROLOGICAL OBSERVATORY ⚠2
- ENVIRONMENTAL OBSERVATORY ⚠2

⚠1 EXCLUDES PM WEIGHT

⚠2 THESE PAYLOADS CAN BE ADDED-ON AS PLUG-IN UNITS TO THE PLATFORM



ADVANCED MULTI-DISCIPLINE PLATFORM – LEO (TYPICAL)

- A manned LEO platform for about 1990 appears somewhat of a certainty. Many of the concepts shown are quite complex; others appear too small for multidiscipline usage or much too large, involving severe logistics problems with transfer of personnel and materials. LMSC proposes consideration of a multidiscipline platform which has a dual function of a fabrication/construction and maintenance base and the potential of earlier implementation (1986-88).

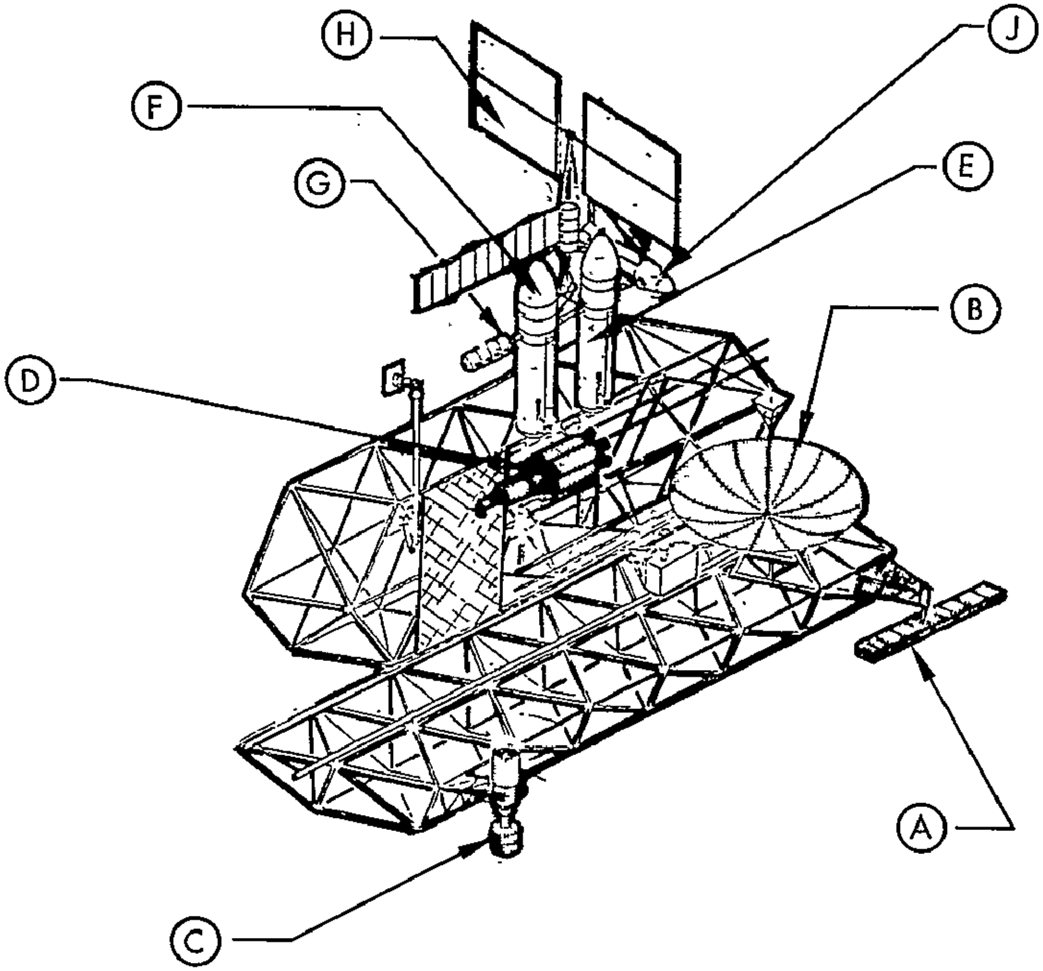
- The basic structure is proposed as a truss-frame type, assembled from earth-fabricated tube elements or beam-machine columns. It would utilize expended External Tanks (ET) for initial structure, with Spacelab-Module crew habitats. It would be expanded to the configuration shown. The ETs would be progressively altered to house fabrication, materials processing, or other equipment.

- Surface areas would be used for fabrication and assembly of the large space structures which would later be transferred to GEO or mounted on exterior parts of the LEO platform for operation.

- A large PM, or multiples of smaller PMs, would be used to provide platform power at 100 kW to 250 kW and attitude control.

- This configuration is conceptual, but is intended to illustrate a composite approach to performing science and operational missions combined with a construction and logistics base, a maintenance/repair facility, an assembly facility for large planetary vehicles and OTVs, and a depot for LEO-GEO-LEO logistics.

ADVANCED MULTI-DISCIPLINE MANNED PLATFORM - LEO (TYP)



- (A) 5X30-METER SOIL MOISTURE SAR
- (B) 100-METER RADIO ASTRONOMY ANTENNA
- (C) 5-M X-RAY TELESCOPE NATIONAL OBSERVATORY II
- (D) PLANETARY SPACECRAFT PLUS PROPULSION ASSEMBLY
- (E) MATERIAL PROCESSING FACILITY (ET)
- (F) PARTS FABRICATION FACILITY (ET)
- (G) CREW HABITAT/CONTROL CENTER
- (H) 100-250 kW POWER MODULE
- (J) SHUTTLE REVISIT

MULTIDISCIPLINE PAYLOAD COMMONALITY CONSIDERATIONS

- It is necessary, when determining the configuration and function of a multidiscipline platform or payload grouping, to consider commonality of requirements as well as compatibility of the various payloads to be combined. This chart lists the general characteristics of several payload disciplines which may impact the selection of payload combinations.

- Orbit is a strong factor; for elements to be moved later to GEO, 28.5 deg LEO is probably most feasible for OTV usage. Most Solar/Terrestrial, Earth Observation, and Hi-energy astronomy payloads are not very useful in this orbit. Conversely, to build/test any Public Services or SPS elements at 57-deg LEO would probably cause redundancy in platforms. Orbit selection therefore seems to point toward more than one multidiscipline platform, initially probably at 28.5 and 57 deg; a full orbit selection tradeoff and selection was not planned for the Part I study because it also involves the tradeoff of revisits and logistic supply by the Shuttle system.

- There does appear to be a common parameter among the various multidiscipline payload choices; this is the use of a large structure for payload support and/or a construction base. Large structure basic approaches are discussed briefly on the following charts.

MULTI-DISCIPLINE PAYLOAD COMMONALITY CONSIDERATIONS

DISCIPLINE	OPERATIONAL MODE/ CHARACTERISTICS	ORBIT – LEO – 28.5 DEG	ORBIT – LEO – 57 DEG	ORBIT – LEO – POLAR	ORBIT – GEO	MANNED	UNMANNED	LOGISTIC SUPPLY – MATL	LOGISTIC SUPPLY – MEN	LOGISTIC SUPPLY – REVISIT	LARGE STRUCTURE	CONSTRUCT. BASE
MATERIALS PROCESSING	AUTOMATED	X	X	X			X	X		X	NO	–
	MAN-TENDED △1	X	X	X		X		X	X	X	NO	–
PUBLIC SERVICES	PROTO FAB/TEST	X					X				YES	–
	OPER. FAB/TEST	X				X		X	X	X	YES	LEO
	ORBIT OPER				X		X				YES	–
SOLAR TERRESTRIAL	FREE-FLYERS		X				X			X	NO	–
	MANNED CLUSTERS		X			X			X	X	NO	–
				X		X			X	X	NO	–
					X	X			X	X	NO	–
SOLAR POWER SYSTEM	PROTO FAB/TEST	X				X		X	X	X	YES	LEO
	OPER FAB/TEST	X				X		X	X	X	YES	LEO
					X	X		X	X	X	YES	GEO
	ORBIT OPER				X		X				YES	–
EARTH OBSERVATION	SMALL PLATFORM		X	X			X			X	NO	–
	LARGE PLATFORM		X	X	X		X				YES	YES
ASTROPHYSICS/ ASTRONOMY	ASTRONOMY	X	X				X			X	NO	–
	HI-ENERGY		X				X			X	NO	–

△1 SAME FOR LIFE SCIENCES

LARGE SPACE STRUCTURE CONCEPT – BEAM MACHINE

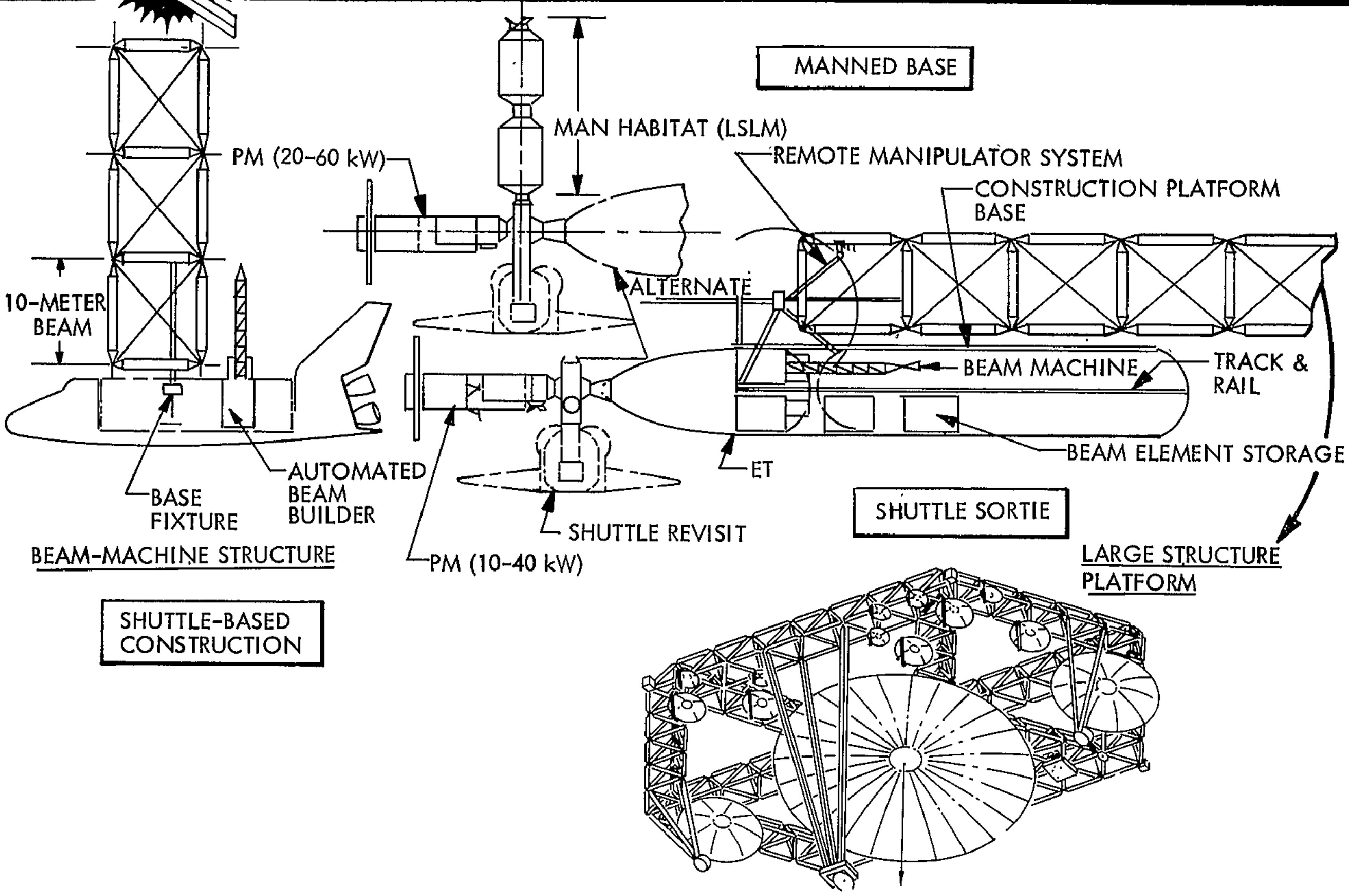
- MSFC has been sponsoring development of a beam-building machine which will provide a basic construction element for large structural platforms. This and the associated construction of a demonstration 10-meter per side triangular beam is shown at the left of the chart. The conversion of this "small" element to a large platform has been proposed. It appears that use of an expended STS External Tank (modified on orbit or prefitted with rails, etc.) is a logical step to an early and potentially cost-effective construction base for large structure platforms up to about 100 meters. PM power for complete platform construction is estimated in a 10 kW to 40 kW range.

- A Shuttle sortie mode is shown, using a PM to provide power and attitude control during the assembly of long beam assemblies and then the assembly of these beams into the completed structure. Although the sortie mode is feasible, the stay-time on orbit to complete the large assembly is fairly long; estimated at up to two 30-day missions.

- It may therefore be desirable to establish a man-habitat base, attaching a pressurized Spacelab Module to the ET and PM combination. This may be better because of the potentially large amount of EVA necessary in the platform construction and the later assembly, attachment and alignment of antennas or other payload elements. The man-habitat raises the PM power to a 20 kW to 60 kW range.

- The initial use of this arrangement as a base would allow use of the man-habitat on an intermittent basis until the platform was completed. It would also provide a good starting point for assembly of a large multidiscipline platform shown on page 1F-11.

LARGE SPACE STRUCTURE CONCEPT - BEAM MACHINE



LARGE SPACE STRUCTURE CONCEPT – TUBE TRUSS

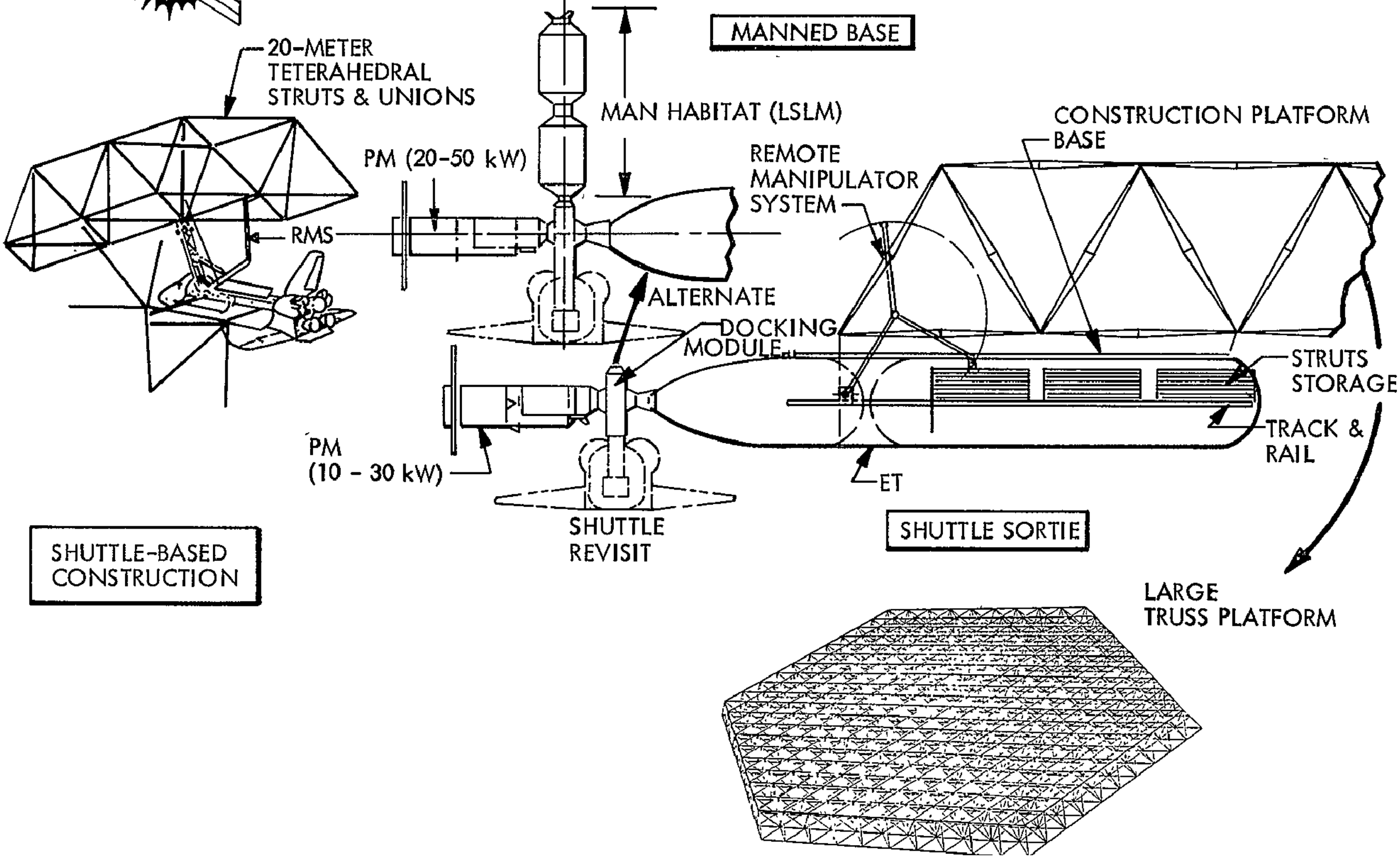
- Three preliminary concepts of tube truss-type large space structures have been investigated (using a NASA/LARC basic concept). These concepts in terms of construction base assembly follow the same pattern as previously described for the beam machine concept.
  - Orbiter-based construction
  - Construction base (ET plus PM) using either Orbiter sortie or manned base as alternate approaches

- The major characteristics of this large structure approach comprise modular arrangement of tetrahedral truss units, fabricated from uniform 20-meter length tube segments and joined by standard fittings. Half-tubes are prefabricated from metal or non-metal composite and delivered to orbit in nested "Dixie-cup" packages.

- The concept on the left side of the chart shows a fundamental Orbiter-based assembly of platform segments. To accelerate the assembly and provide for less stay-time on orbit of the Orbiter, a semi-automated construction mode is probably desirable; this is shown in the "Shuttle Sortie" mode, wherein an ET fitted with assembly equipment is supported with power and attitude control by a PM (10 kW to 30 kW).

- Because EVA may become a predominant assembly mode as the platform assembly becomes larger and assembly time increases, an alternate manned-base approach may be desirable. The use of a man-habitat will raise the PM power requirement to a range of 20 kW to 50 kW. Features of interchangeability of assembly equipment and potential for building up to larger construction and operational platforms are also important in selection of an assembly method and should be considered in "standardizing" the large structures scenario.

LARGE SPACE STRUCTURE CONCEPT – TUBE TRUSS



SUMMARY PAYLOAD REQUIREMENTS AS POWER MODULE DRIVERS

SUMMARY PAYLOAD POWER REQUIREMENTS – kW

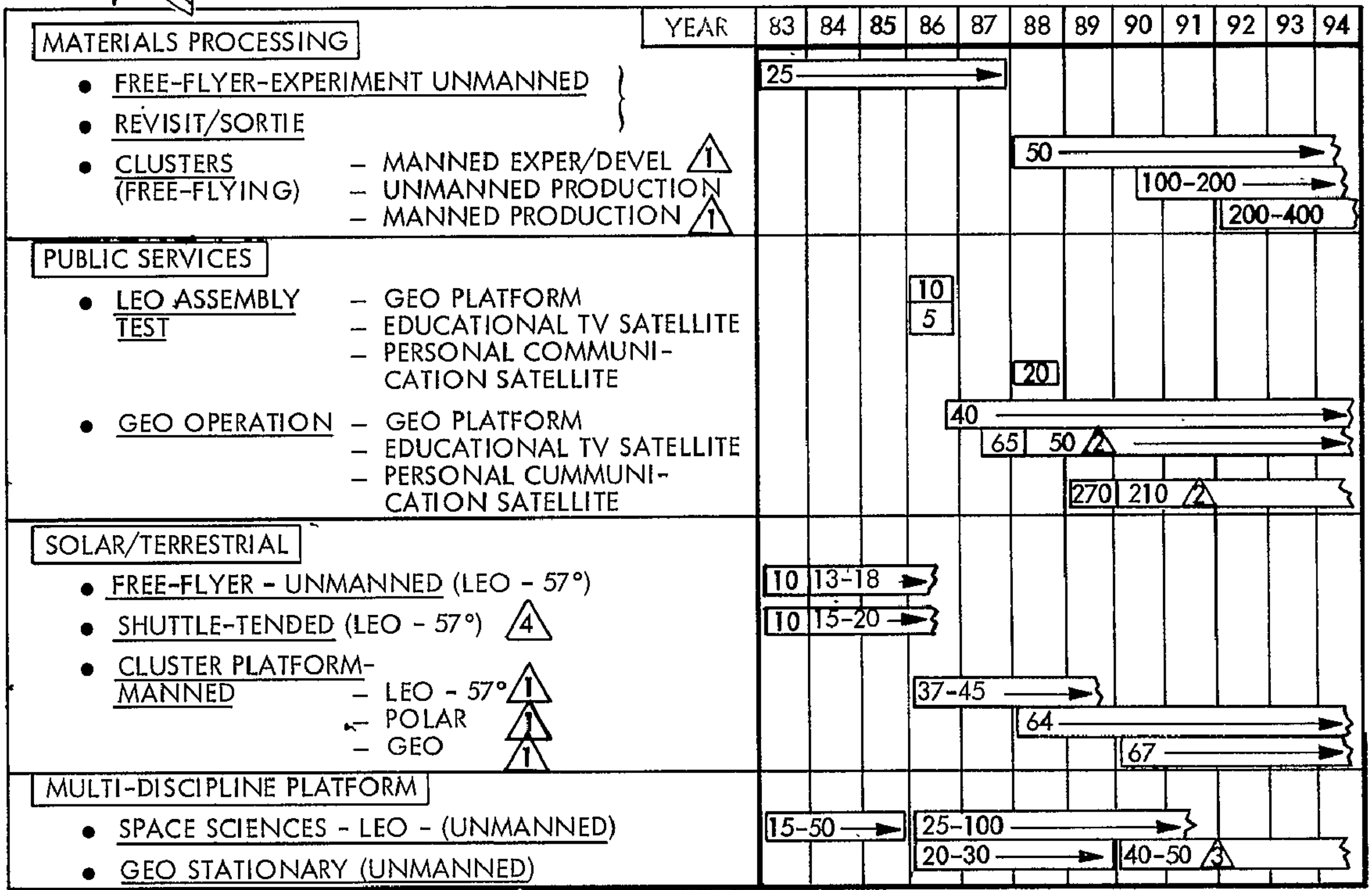
- This chart summarizes the power requirements for major elements of the three emphasis payload disciplines and provides estimates for two typical multi-discipline platforms. The Materials Processing free-flyer and combined sortie missions indicate the earliest need for a 25 kW PM is in LEO starting in 1983. In 1984 the Solar/Terrestrial missions may also require power levels up to about 20 kW. The Multi-Discipline platform may become a strong driver also in 1983 or 1984, depending upon the complement of payloads carried.

- The first growth-version PM appears to be strongly driven by the LEO Solar/Terrestrial manned platform with IOC 1986 and power level of about 37 kW (including 17 kW to support the manned display/control module and habitat). Power requirements for further PM growth in LEO appear in 1988 for the Materials Processing manned cluster at about 50 kW and in the Polar Solar/Terrestrial platform at about 64 kW. The same growth-version PM could be used for enlarged versions of the Multi-Discipline platform.

- Support of Public Services payloads starts in late 1986, with a potential of using the PM for powering ion-engine transfer from LEO to GEO. Power levels range from 40 kW up to 270 kW.

- In summary, there are several payload disciplines which require a 25 kW PM support in 1983, with a probable step increase about 1986 to the 40-50 kW level. Later power requirements in the early 1990s will range between 100 kW to about 400 kW.

SUMMARY PAYLOAD POWER REQUIREMENTS -KW



1. PAYLOAD REQUIREMENTS PLUS 7 kW FOR PRESSURIZED PAYLOAD MODULE PLUS 10 kW FOR MAN SUPPORT HABITAT
2. REDUCTION DUE TO TRANSFER LOSS LEO-TO-GEO
3. PLUG-IN PAYLOAD MODULE ADDITIONS
4. ORBITER REQUIRES ADDITIONAL 14 kW IN THIS SORTIE MODE

MAJOR PAYLOAD HEAT REJECTION CHARACTERISTICS

- Heat rejection from payloads will probably vary considerably in actual hardware implementation. In many cases it will be desirable to mount separate radiators on the individual payload element; this mode appears to be appropriate when modules or pallets are not connected directly to the PM or located at some distance remote from the PM interface.

- Use of combined cooling using both payload and PM radiators may also involve special interfacing. For example, the Materials Processing payload radiator loop operates at a higher temperature than the PM loop. In some cases separate payload radiators also present potential mechanical clearance, thermal shading, radiation, and similar problems. Payload cooling and radiator design will require special attention as specific payload designs are implemented in later studies and hardware programs.

- The chart is a general summary of approximate heat rejection levels for the major payload disciplines. Alternatives are shown between integral payload radiators and fluid-loop connections with either the Orbiter or the PM. Specific tradeoff of these alternatives will be necessary in follow-on studies of radiator size, placement, and interfaces.

- Heat rejection requirements of the payloads studied exceed the Orbiter capability. In some cases where the PM radiators are used, the payload may be a driver for sizing the PM radiators or requiring that major payload heat loads will be rejected by integral payload radiators.

MAJOR PAYLOAD HEAT REJECTION CHARACTERISTICS

PAYLOAD/MODE	REQUIRED OPERATION	REJECTION LEVEL (kW)	ALTERNATIVES	
			INTEGRAL PAYLOAD RADIATORS	FLUID LOOP CONNECTIONS
MATERIALS PROCESSING				
• FREE-FLYERS – PALLETS – MEM-I	1983	22	PALLETS; MEM	PM DISCONNECT
• SORTIE/REVISIT	1983	5-15	LAB; PALLETS (1)	ORBITER DISCONNECT
• MANNED EXPER/DEVEL CLUSTER	1988	40	EACH MODULE	–
• UNMANNED PRODUCTION CLUSTER	1990	90-180	EACH MODULE	–
• MANNED PRODUCTION CLUSTER	1992	180-360	EACH MODULE	–
PUBLIC SERVICES				
• LEO ASSEMBLY TEST	1984-88	2-15	ON PAYLOAD	PM DISCONNECT
• GEO OPERATIONS	1986-88	15-160	ON PAYLOAD	PM PERMANENT
SOLAR/TERRESTRIAL				
• FREE-FLYER PALLETS	1983	8-12	PALLETS (2)(3)	PM DISCONNECT
• SOLAR POINTING PACKAGE	1983	<1	PASSIVE RAD	–
• SORTIE/SHUTTLE-TENDED	1983	8-18	PALLETS (1)(2)(3)	ORBITER DISCONNECT
• LEO MANNED CLUSTER (4)	1986	30-40	PALLETS & MODULES (1)(2)(3)	–

(1) INTERFACE BETWEEN PAYLOAD AND SHUTTLE RADIATORS MAY BE PROBLEM
(2) INTEGRAL PAYLOAD RADIATORS POSSIBLE INTERFERENCE WITH PAYLOAD FIELD OF VIEW
(3) PALLETS MAY REQUIRE HINGED RADIATORS TO ACCOMMODATE VARYING ORIENTATIONS
(4) PM MAY REQUIRE HINGED RADIATOR PANELS FOR USE WITH CLUSTER ARRANGEMENT

PAYLOAD STABILIZATION/CONTROL REQUIREMENTS

- The pointing accuracy range for several of the major payloads investigated is shown on the chart. In general, these are beyond the capability anticipated for a support vehicle such as the PM. Therefore, it has been assumed that integral gimbals and other payload-integral devices will be utilized to obtain the extra-fine pointing requirements less than 30 arc sec.

- The Solar/Terrestrial payload groups offer the most challenge for a PM control system, primarily because of the large variation in target direction. Some of this can be accommodated by mounting of the instrument on the pallet or orienting the pallet mechanically relative to the PM. However, several of the payloads will require re-orienting the PM/payload cluster during an orbit cycle rather than flying inertially stable. These conditions must be further analyzed in future study of the PM control characteristics.

- The Materials Processing payloads require a special low (10^{-5}g) continuous environment and very low rotation rate of one rev/hr.; this will place a separate requirement upon the PM controls.

PAYLOAD STABILIZATION/CONTROL REQUIREMENTS

DISCIPLINE	TARGET ORIENTATION	POINTING ACCURACY/CONTROL ⚠1
MATERIALS PROCESSING	ANY	• 10^{-5} G • 1 REV/HR (MAX)
PUBLIC SERVICES	NADIR	0.01 TO 0.5 DEG
SOLAR/TERRESTRIAL • SOLAR PHYSICS • ATMOS/MAGNETOSPHERE	 SOLAR • NADIR • EARTH LIMB • MAGNETIC LINES	 0.1 TO 30 ARC SEC 10 ARC SEC TO 2 DEG
ASTROPHYSICS/ASTRONOMY	• INERTIAL-STELLAR • CELESTIAL SPHERE	0.1 TO 30 ARC SEC 0.1 ARC SEC TO 1 DEG
EARTH OBSERVATION	NADIR	6 ARC SEC TO 1 DEG

⚠1 INTEGRAL GIMBALS AND OTHER PAYLOAD FINE-POINTING DEVICES MAY BE PROVIDED WITH PAYLOADS TO MEET FINE-POINTING LIMITS.

PAYLOAD ORBIT OPERATION MAJOR DURATION REQUIREMENTS

- This chart lists the desired on-orbit durations for several of the major payloads and a reason for the durations suggested. For the platform-mounted payloads, Orbit revisits would be scheduled for instrument repair or adjustment. For the manned platforms, 90-day revisit cycles would probably be necessary for personnel rotation.

- The unmanned free-flyer involves the earliest long-duration requirement (in 1983) for both Materials Processing and Solar/Terrestrial payloads. Early multi-discipline platforms could also enlarge this requirement that could vary from 30 to 280 days.

- The introduction of the large structure assemblies would involve man-supported (including EVA) operations that probably involve a minimum of 30 days and as many as 60 to 90 days.

- The PM is required to support these longer – duration missions, the shortest of which is estimated to require 30 days.

PAYLOAD ORBIT OPERATION MAJOR DURATION REQUIREMENTS

PAYLOAD/MODE	MISSION DURATION DESIRED	REASON
MATERIALS PROCESSING		
• FREE-FLYER MODE	280 DAYS/YEAR	• UP TO 800 EXPERIMENTS ⚠2 PER YEAR PLANNED; DUPLICATE PROCESSING EQUIPMENT AND MINIMUM QUANTITY ORBITER REVISITS REQUIRED TO OBTAIN LOW UNIT COST OF EXPERIMENT
PUBLIC SERVICES		
• LEO ASSEMBLY/TEST	30-180 DAYS	• LARGE ASSEMBLIES/ALIGNMENT; TESTING
• GEO OPERATIONS	10-15 YEARS	• LONG-TERM FACILITY AMORTIZATION
SOLAR/TERRESTRIAL		
• UNMANNED FREE-FLYER	1 YEAR	• OBSERVE PHENOMENA THROUGH SEVERAL SOLAR REVOLUTIONS; SEASONAL EFFECTS
• MANNED PLATFORMS	1-3 YEARS	• MAXIMIZE SOLAR EVENT OBSERVATIONS (DIRECT MAN REACTION TIME)
ASTROPHYSICS/ASTRONOMY		
• PLATFORM-MOUNTED	1-10 YEARS	• LONG-TERM VIEWING ALLOWS MORE OBSERVATIONS PER MISSION AT LOWER COST
LARGE PLATFORM STRUCTURE ASSEMBLY		
• MANNED OPERATIONS	60-90 DAYS ⚠1	• ASSEMBLY OF MANY SEPARATE STRUCTURAL AND PAYLOAD ELEMENTS

⚠1 COULD BE LONGER; DEPENDENT ON PLATFORM SIZE

⚠2 SINGLE EXPERIMENT TIME RANGES FROM ONE TO 120 HOURS; ORBITER REVISIT AT 60-DAY INTERVALS FOR MATERIAL/PRODUCT CANNISTER EXCHANGE

PAYLOAD COMMUNICATIONS AND DATA HANDLING (C&DH) REQUIREMENTS

- In general, the communications and data handling characteristics for future payloads have not been well-defined. However, estimates have been made for the three major disciplines and are shown on the chart in generalized form. All data transmission requirements appear to exceed the baseline PM capability. The Solar/Terrestrial payload groupings have the highest data rates, in the MBPS range.

- It has not been determined whether it is more mission effective and cost-effective to increase the nominal capability of the PM to handle payload data processing. However, it appears that processing of P/L housekeeping-status data and transmission of basic command data may be a good minimum C&DH ground rule for the PM. The other basic alternatives for payload groups must be traded-off as payload concept designs are defined in later studies. This is particularly true of multi-discipline payload platforms where consolidation of payload C&DH equipment offers some advantages (composite computers, common antennas).

PAYLOAD COMMUNICATIONS AND DATA HANDLING (C & DH) REQUIREMENTS

GENERAL REQUIREMENTS			DATA TRANSMISSION ⚠1
• MATERIALS PROCESSING	– UNMANNED FREE-FLYER	1983-86	• 10 KBPS DIGITAL • 4 MHz ANALOG (VIDEO)
	– MANNED CLUSTERS	1988	• TBD
• PUBLIC SERVICES	– LEO-TEST DATA	1986-89	• 500 KBPS
	– GEO-HOUSEKEEPING DATA	1986-1990	• USES PAYLOAD CHANNELS
• SOLAR/TERRESTRIAL	– UNMANNED FREE-FLYER	1983-86	• 5-35 MBPS DIGITAL • 10 MHz ANALOG (VIDEO)
	– MANNED PLATFORMS	1986-89	• 15-25 MBPS DIGITAL • 25 MHz ANALOG (VIDEO)

ALTERNATIVE IMPLEMENTATION APPROACHES

(1) SEPARATE C&DH EQUIPMENT ON INDIVIDUAL PAYLOAD HARDWARE ELEMENTS

(2) COMPOSITE PAYLOAD C&DH PACKAGE FOR EACH MAJOR PAYLOAD GROUPING (PALLET, OR GROUP OF PALLETS – SIMILAR TO SPACELAB IGLOO)

(3) PROVIDE LARGER C&DH CAPABILITY ON POWER MODULE

⚠1 PRELIMINARY ESTIMATES ONLY; LIMITED SPECIFIC DATA AVAILABLE ON ADVANCED PAYLOADS.

SUMMARY OF PAYLOADS REQUIRING POWER MODULE SUPPORT

- This chart summarizes the requirements described earlier. The principal PM driver is power level However, mission duration and attitude control are very important. Heat rejection also will be a strong driver if it is decided to use the PM radiators in lieu of separate payload-integral radiators. Specific numbers have been entered for the three emphasis disciplines; for the other disciplines, "X" is shown to indicate the area needing PM support.

- A 25 kW PM is needed in 1983 for power level, long duration on orbit, and attitude control. In 1986-1988 a growth version of the PM supplying 37 to 64 kW will be required. Larger growth versions with capability to 200 kW will be required by 1990. Beyond that point, estimates indicate power levels may rise to the 200-400 kW range as manned platforms are expanded.

- All of these estimates are based upon the composite of the three disciplines, Materials Processing, Public Services, and Solar/Terrestrial. The alteration of missions within any of the disciplines should not grossly affect the need for the PM but may impact the power level. It must be recognized, however, that the requirements for the SPS and other payloads have not been included in the power requirements summaries; also, the multi-discipline platform is a strong separate driver. In summary, there appears to be strong justification for a PM initially in 1983 and for early growth versions.

SUMMARY OF PAYLOADS REQUIRING POWER MODULE SUPPORT

PAYLOAD TYPE	FLIGHT MODE	IOC EARLY	IOC LATER	POWER MODULE JUSTIFICATION: POWER (kW)	HEAT REJECTION (kW)	MISSION DURATION	ATTITUDE CONTROL ⚠1
MATERIALS PROCESSING							
	• LEO-FREE-FLYER PALLETS • LEO-FREE-FLYER MEM-I	1983		25	22	280 DAYS	G
	• LEO-MANNED CLUSTER-EXPER. ⚠2		1988	50	45	365 DAYS	G
	• LEO-UNMANNED PROD. CLUSTER		1990	100-200	90-180	365 DAYS	G
	• LEO-MANNED PROD. CLUSTER ⚠2		1992	200-400	180-360	365 DAYS	G
PUBLIC SERVICES	• GEO-GEOSTATIONARY PLATFORM	1986		40	15	365 DAYS	P
	• GEO-EDUC. TV SAT.		1988	50	40	365 DAYS	P
	• GEO-PERS COMM SAT		1990	210	160	365 DAYS	P
SOLAR/TERRESTRIAL	• LEO-SHUTTLE-TENDED	1983-84		10-20	4-14	30-90 DAYS	P, C
	• LEO-FREE-FLYER	1983-84		10-18	8-14	1-2 YRS	P, C
	• LEO-MANNED CLUSTER ⚠2		1986	37-64	30-55	1-3 YRS	P, C
	• GEO-MANNED CLUSTER ⚠2		1990	67	53	1-3 YRS	P, C
ENERGY SYSTEMS-SPS	• LEO-DEMO ARTICLE FAB	1985		X		X	P
	• LEO-ANTENNA FAB		1989	X		X	P
	• LEO-SOLAR ARRAY FAB		1996	X		X	P
	• GEO-SOLAR ARRAY FAB		1997	X		X	P
ASTROPHYSICS/ASTRONOMY	• LEO-FREE-FLYER	1984				X	P, C
EARTH OBSERVATION	• LEO-FREE-FLYER	1984		X	X	X	P, C
LIFE SCIENCES	• LEO-SORTIE	1984				X	G
	• LEO-PLATFORM		1986	X	X	X	G
CONSTRUCTION BASE	• LEO-SMALL	1986		X		X	P
	• LEO-LARGE		1988	X		X	P
MULTI-DISC. PLATFORM	• LEO-FREE-FLYER	1983		X		X	P, C
	• LEO-PLATFORM		1986	X		X	P, C

⚠1 P = POINTING/ATTITUDE; C = CONTAMINATION CONTROL; G = G-LEVEL

⚠2 POWER INCLUDES SUPPORT FOR PAYLOAD PRESSURIZED CONTROL MODULE AND MAN HABITAT; APPROX. 17 kW

CONCLUSIONS/ RECOMMENDATIONS

PAYLOAD DRIVERS FOR PM – EARLY AND GROWTH

- The general payload requirements are outlined differently on this chart, emphasizing the principal PM drivers and the payload discipline. The early 1983-84 PM is driven principally by the Materials Processing and Solar/Terrestrial disciplines. If the Multidiscipline payload groupings are applied early, their combined requirements would be very similar.

- The PM power growth driver disciplines are the same except that Public Services applies a strong impact starting in 1986 and supplies the first requirement for GEO mission application of a PM.

PAYLOAD DRIVERS FOR PM - EARLY AND GROWTH

	LEVEL	DRIVER DISCIPLINE
EARLY DRIVERS - 1983-84		
• POWER	– 25 kW	MATERIALS PROCESSING
	– 10-20 kW	SOLAR/TERRESTRIAL
• HEAT REJECTION	– 22 kW △1	MATERIALS PROCESSING
	– 8-18 kW △1	SOLAR/TERRESTRIAL
• DURATION	– 280 DAYS/YEAR	MATERIALS PROCESSING
	– 30 DAYS TO 1 YEAR	SOLAR/TERRESTRIAL
• ATTITUDE CONTROL	– 30 ARC SEC OR LESS △2	SOLAR/TERRESTRIAL
	– MANY ATTITUDES	SOLAR/TERRESTRIAL
	– 10^{-5} G	MATERIALS PROCESSING
GROWTH POWER DRIVERS		
• 1986	– 35 kW (LEO)	SOLAR/TERRESTRIAL
	– 50 kW (GEO)	PUBLIC SERVICES
• 1988	– 50 kW (LEO)	MATERIALS PROCESSING
	– 210 kW (GEO)	PUBLIC SERVICES
• 1990s	– 100-400 kW (LEO)	MATERIALS PROCESSING

△1 RADIATORS MAY BE INTEGRAL WITH PAYLOAD

△2 ASSUMING CRITICAL-ACCURACY PAYLOADS HAVE INTEGRAL GIMBALS

CONCLUSIONS – PART I

- The upper portion of the chart emphasizes that future payload planning is currently dynamic. Recent changes have resulted from conversion of the previous payload concepts, which were Orbiter-constrained, to a new approach where increased power and time-on-orbit has become available with the introduction of the PM. For this reason, payload program planning and new concepts must be carefully and periodically reassessed as the PM is developed.

C-3

- Because of the required orbit positioning of certain payloads, PM dedication may be required to a single orbit. In fact, with high power requirements for particular payload groups, and to support the longer-duration missions, a PM may also be dedicated to single-discipline payload or groups – or to a multidiscipline cluster (examples: Materials Processing or Solar/Terrestrial).

CONCLUSIONS - PART I

DYNAMIC STATUS OF PAYLOADS

- PREVIOUS DETAIL PLANNING/CONCEPTS FOR PAYLOADS CONSTRAINED TO:
  - AUTONOMOUS FREE-FLYER SATELLITES; RELATIVELY LOW POWER
  - LIMITED-DURATION FLIGHTS WITH SHUTTLE-ONLY SUPPORT (SPACELAB)
  - PAYLOADS USING MAN-SUPPORT ON ORBIT
  - PRIMARILY DEVOTED TO 1980-83 HARDWARE CONCEPTS
- HEAVY CONVERSION OF PAYLOAD CONCEPTS NOW IN PROCESS:
  - EXTENDED-DURATION SHUTTLE SORTIES; WITH PM
  - FREE-FLYER PM-SUPPORTED MISSIONS
  - AUTONOMOUS PAYLOAD OPERATION – UNMANNED
  - PAYLOAD COMBINATIONS ON MULTI-DISCIPLINE PLATFORMS

PM ORBIT PLACEMENT AND DEDICATED USAGE

- PRINCIPAL ORBITS ACCOMMODATING MOST PAYLOADS:

LEO	GEO
– 28.5 DEG	
– 57 DEG	
– POLAR	

- DEDICATED PMs MAY BE REQUIRED EARLY (1983-86) TO PROVIDE:
  - POWER LEVEL TO SUPPORT SINGLE PAYLOAD OR CLUSTER
  - SPECIFIC ORBIT POSITIONS

CONCLUSIONS – PART I (Continued)

- The general applications for PMs are broadly summarized on this chart. The principal need is to support early free-flyer payloads in 1983.

- For early flights requiring man-support on a sortie mission, the PM will support not only the Orbiter-installed payload equipment but will permit docking to a free-flyer PM/payload on orbit as is required for Solar/Terrestrial and Materials Processing development flights where combined instrument runs are conducted.

- In summary, there are multiple needs for the PM. Although some may be altered downstream as a result of reprogramming or funding allocations, the composite of all needs appears to form a solid base for development of a PM to support the future NASA payloads.

CONCLUSIONS - PART I (CON'T)

(2 OF 3)

GENERAL NEED FOR POWER MODULES

- EARLY FREE-FLYERS – THE POWER MODULE IS REQUIRED TO SUPPORT FREE-FLYER PAYLOADS. STARTING IN 1983 (MATERIALS PROC, SOLAR/TERRES)
- SORTIE SUPPORT – PM ALSO NEEDED TO SUPPORT LONGER-DURATION SORTIE FLIGHTS WITH ORBITER ATTACHED TO PM/PAYLOAD FREE-FLYER.
- DEDICATED PMs – PROBABLY REQUIRED FOR HIGH-POWER AND LONG-DURATION MISSIONS
- GEO PAYLOADS – PM CAN PROVIDE SUPPORT TO GEO PAYLOADS:
  - LEO TEST ARTICLES AND GEO SUBASSEMBLY FABRICATION
  - ION THRUSTER POWER FOR ORBIT TRANSFER
  - GEO OPERATION
- MULTI-DISCIPLINE PAYLOAD GROUPS – STRONG BASIS FOR PM INCREASED POWER REQUIREMENT ASSOCIATED WITH LARGER PALLET GROUPS, MODULE CLUSTERS, OR STRUCTURAL PLATFORMS
- LARGE SPACE STRUCTURES – EXTENDED-DURATION ASSEMBLY OPERATIONS WILL REQUIRE PM SUPPORT
- MAN HABITATS – FREE-FLYING MANNED PAYLOAD CLUSTERS OR PLATFORMS WILL REQUIRE PM SUPPORT

CONCLUSIONS – PART I (Continued)

- This chart offers a condensed summary of payload requirements resulting from the Part I study in the areas having primary impact on the PM subsystems.

- This data, reinforced by specifics offered earlier in the report, will be used in defining the growth concept of the PM in Parts II and III of the study.

- The baseline Power Module is primarily responsive to Orbiter sortie mode requirements. Data handling and control pointing accuracy for free-flyers present potential requirements for modification of the baseline.

CONCLUSIONS - PART I (CON'T)

PAYLOAD IMPACT ON PM SUBSYSTEMS AND SUPPORT ELEMENTS

- POWER
  - MINIMUM OF 25 kW REQUIRED IN 1983 FOR FREE-FLYER OR SHUTTLE-TENDED (MATERIALS PROCESSING, SOLAR/TERRESTRIAL)
  - GROWTH TO 40 kW (1986) FOR LEO PLATFORM (SOLAR/TERRESTRIAL)
  - GROWTH TO 50 kW (1988) AND THEN TO 100-400 kW (1990-1992) FOR CLUSTERS/PLATFORMS (MATERIALS PROCESSING)
- HEAT REJECTION
  - SOME PAYLOADS MAY REQUIRE SEPARATE RADIATORS BEYOND SHUTTLE/PM CAPABILITY
  - SOME FREE-FLYER PAYLOADS MAY EXCEED 25 kW PM BASELINE CAPABILITY
  - PAYLOAD CONFIGURATION/MOUNTING MAY FORCE INDEPENDENT PAYLOAD RADIATORS
- DURATION ON ORBIT
  - BEYOND 30 DAYS REQUIRED ON MOST PAYLOADS (MATERIALS PROCESSING, SOLAR/TERRESTRIAL)
- STABILITY/CONTROL
  - MODEST FOR MANY PAYLOADS; APPROXIMATELY ±0.5 DEG OR LARGER. CRITICAL-ACCURACY PAYLOADS MAY REQUIRE INTEGRAL GIMBALS.
- LOW-G FORCE
  - 10^{-5} G FOR EXTENDED TIMES (120 HR) (MATERIALS PROCESSING)
- CONTAMINATION
  - USE OF NON-EXPULSION ACS (CMGs) DESIRABLE FOR SEVERAL PAYLOADS (ASTROPHYSICS/ASTRONOMY, SOLAR/TERRESTRIAL)
- DATA PROCESSING
  - SELECTED PAYLOAD GROUPINGS REQUIRE DATA HANDLING IN MBPS RANGE (SOLAR/TERRESTRIAL)

PART I RECOMMENDATIONS FOR PRIMARY MISSION EMPHASIS

- Shown on the chart are three principal recommendations for concept development of the PM in Parts II and III.

- Because of the tentatively dynamic changing aspects of the SPS program, it has not been included in the proposed driver payload disciplines.

- If study time permits, it will be desirable to update the requirements for the Multi-Discipline Platform as the MSFC concepts are developed in coordination with NASA/HQ.

PART I RECOMMENDATIONS FOR PRIMARY MISSION EMPHASIS

- CONCENTRATE POWER MODULE CONCEPTS ON FOUR DRIVER PAYLOAD DISCIPLINES:
  - BASELINE (1983)
    - MATERIALS PROCESSING
    - SOLAR/TERRESTRIAL
  - GROWTH (1986)
    - PUBLIC SERVICES
    - MATERIALS PROCESSING
    - SOLAR TERRESTRIAL
    - MULTI-DISCIPLINE PLATFORM
- CONSIDER USE OF PM DERIVATIVES TO SUPPORT GEO PAYLOADS:
  - PUBLIC SERVICES (IN LIEU OF INTEGRAL P/L POWER SUPPLY)
  - SOLAR/TERRESTRIAL
- REVIEW PAYLOAD REQUIREMENTS PRIOR TO COMPLETION OF PART II FOR SIGNIFICANT PM IMPACT CHANGES

GENERAL RECOMMENDATIONS FOR FOLLOW-ON ACTIVITY ON PAYLOADS

- Because of time and resources constraints on the Part I study, all of the future NASA payloads could not be analyzed. Contributing to this partial analysis was the dynamic status of future planning in changeover to the PM usage concept. In this context, the recommendations on the chart are recommended for follow-on activity beyond the current 25 kW Power Module Evolution Study.

- Of principal importance is the definition of additional payload scenarios and the concept definition of major payloads supporting these scenarios. Currently, many alternatives exist within the same payload discipline.

- The continued efforts of a consolidated NASA User-Needs activity appears mandatory in filtering and consolidating not only summarized Users requirements but in sponsoring preparation of a Users Payload Requirements document. This will conceptually define the payloads to be flown in terms that provide a firm base for: (1) PM and Support System element design and, (2) payload and PM system interface definition.

- In addition to explicit payload disciplines, the Multi-Discipline Payload Platform(s) and the selection of a common structural approach for large platforms merit strong emphasis.

GENERAL RECOMMENDATIONS FOR FOLLOW-ON ACTIVITY ON PAYLOADS

- INTEGRATE RESULTS OF NASA USER NEEDS INTO UPDATED PM REQUIREMENTS SUPPLEMENTING PART I ACTIVITIES ON A CONTINUING BASIS
- ESTABLISH A NASA USERS PAYLOAD REQUIREMENTS DOCUMENT DIRECTED TOWARD PM APPLICATION OPPORTUNITIES
- EXPAND AND MAKE FIRMER NASA PAYLOAD SCENARIOS BEYOND 1986 IN SELECTED PM-DRIVER DISCIPLINES (E.G., MATERIALS PROCESSING NOW LIMITED TO 1981-86)
- INITIATE ADDITIONAL NEAR-TERM STUDY OF MULTI-DISCIPLINE PAYLOAD PLATFORMS EMPHASIZING PM USAGE; COMBINE EXPERIMENTS, ENGINEERING DEMONSTRATION, AND OPERATIONS
- DEFINE CLEARLY AN OVERALL COMMON DEVELOPMENT PROGRAM FOR LARGE STRUCTURAL PLATFORMS AND SPACE CONSTRUCTION BASE(S) AS SUPPORT TO ALL ADVANCED DISCIPLINES: EARLY IOC - 1986

BIBLIOGRAPHY – PART I

25 kW POWER MODULE EVOLUTION STUDY

The following pages list the primary published-document references to payload data used for Part I of the study. The documents describing the Power Module and major elements of the Support Systems (Orbiter, External Tank, Spacelab Modules/Pallets, etc.) were also reviewed for general information but their listing has not been included herein; they will be listed as specific references in the Part II and Part III reports to be issued at a later date.

Ref. No.	Document No.	Title	Author/Source/Contract	Date
1		"NASA 5-Year Planning – Fiscal Years 1979 – 1983"	NASA/HQ (Attached to John Naugle letter, same title)	1 Mar 1978
2	JSC-13829 Rev. 1	"NASA STS Mission Model" Payload Descriptions and Space Transportation System Cargo Manifests	NASA/JSC	Oct 1977
3	NASA SP-387	"A Forecast of Space Technology – 1980-2000"	NASA/HQ	Jan 1976
4	NASA SP-386	"Outlook for Space" – Report to NASA Administrator	NASA/HQ (Outlook for Space Study Group)	Jan 1976
5	ATR-76 (7365)-1	"Advanced Space System Concepts and Their Orbital Needs (1980-2000)"	Aerospace Corp. – I. Bekey, H. L. Mayer, M. G. Wolfe	Dec 1976
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